CODE OF PRACTICE FOR MAINTENANCE OF BITUMINOUS ROADS

(Second Revision)

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3	Secretary General, Indian Roads Congress	Nirmal, S.K.

CODE OF PRACTICE FOR MAINTENANCE OF BITUMINOUS ROADS

1. INTRODUCTION

IRC:82 was first published in the year 1982 and was subsequently revised during the year 2015. Due to the continuous changes and advancement in the technology related to Planning of Maintenance Activities based on Rating, Type, Identification, Causes and Treatment of Distresses, Materials and Methods etc., it was decided to further update this Code. The Road Maintenance and Asset Management Committee (H-6) of IRC took up this task of revision and the task was assigned to Dr. Pradeep Kumar, Subgroup Chairman who was well supported by Dr. A. Veeraragavan and Shri D.P. Gupta. The draft was deliberated in various meetings of H-6 Committee and was finalized in its meeting held on 24.03.2022.

The composition of H-6 Committee is given below:

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Director General (Road Development) & Special Secretary to Govt. of India	(Nirmal, S.K.) Ministry of Road Transport and Highways
Secretary General, Indian Roads Congress	(Nirmal, S.K.)

The revised draft document was placed before the Highways Specifications and Standards Committee (HSS) in its meeting held on 04.06.2022. After detailed deliberations, HSS decided to refer back the draft document to H-6 Committee for incorporation of suggestions offered during the meeting. The draft was again discussed in various meetings of H-6 Committee and was finalized in its meeting held on 15.09.2022. The modified draft was again placed during the HSS meeting held on 24.09.2022. The HSS Committee approved this draft revision subject to suitably incorporating written and verbal comments received and also recommended it for placing before the meetings of Executive Committee (EC) and Council. The EC in its meeting held on 07.10.2022 approved the draft revision for placing before the Council. The 223rd Council in its meeting held on 8th October, 2022 at Lucknow (Uttar Pradesh) considered and approved draft second revision of IRC:82 "Code of Practice for Maintenance of Bituminous Roads" for printing.

2. SCOPE

The scope of the document is as under:

2.1 By early detection of distress and appropriate repair of bituminous surface at initial stages, further deterioration of the pavement surface can be prevented or delayed. This code of Practice deals only with the "Routine", "Preventive" and "Periodic" maintenance of bituminous surfaces.

2.2 Several phases are involved in undertaking maintenance operations for bituminous surface as discussed in subsequent sections. Sections 3 and 4 deal with importance and types of maintenance. Maintenance planning and system approach to pavement maintenance are described in Sections 5 and 6, respectively. Types of pavement distresses, identification, severity, their causes, and methods of treatment are given in Section 7.

2.3 Preventive maintenance is the need of the day and is described in section 8. Periodic renewals are covered in Section 9. Sections, 10, 11, 12, and 13 deal with the materials and methods for rectification, tools and equipment, arrangements for traffic, and organization and management, respectively.

2.4 Operations falling in the category of pavement rehabilitation and strengthening are beyond the scope of this Code of Practice. For design of rehabilitation and strengthening measures for existing pavements, reference may be made to the following publications:

i) IRC:81 "Guidelines for Strengthening of Flexible Road Pavements using Benkelman Beam Deflection Technique"

ii) IRC:37 "Guidelines for the Design of Flexible Pavements"

iii) IRC:115 "Guidelines for Structural Evaluation and Strengthening of Flexible Road Pavements using Falling Weight Deflectometer (FWD) Technique"

3. IMPORTANCE OF MAINTENANCE

3.1 The timely upkeep and maintenance of bituminous surfacing offers numerous benefits for preservation of road asset. The importance of overall maintenance is described below:

i) Reduction in rate of deterioration and improvement in life of road

ii) Reduction in Vehicle Operation Costs (VOC)

iii) Reduction in crash rate

iv) Keeping road traffic worthy roads in all weather conditions

v) Reduction in pollution due to reduced fuel consumption on well-maintained pavement surface

vi) Savings in budgetary expenditure of restoration/ reconstruction

3.2 Timely and regular maintenance of roads have been known to provide economic rate of return as high as 15 to 20 percent depending upon the category of road and traffic volume. Moreover, it helps in deferring the demand for rehabilitation which otherwise is far costlier than preventive maintenance. Therefore, timely and appropriate maintenance of bituminous surface using sustainable/suitable materials and methods is significant for preservation of road asset and to serve the intended purpose.

4. TYPES OF MAINTENANCE

4.1 Maintenance operations covered in this Code of Practice are classified into three broad categories

a) **Routine Maintenance:** This covers items such as filling of potholes, repairing of cracks and patch work, shoulder dressing, drain desilting etc., which are undertaken by the maintenance staff all through the year. Routine maintenance is also required for pavement markings on the bituminous surfaces to guide the road users and enhance road safety.

b) **Preventive Maintenance:** Preventive maintenance is performed to improve or extend the functional life of pavement surface while in good structural condition. This may defer the timing for periodic maintenance and rehabilitation during the design life.

c) **Periodic Maintenance:** This includes regular maintenance operations compared to preventive maintenance such as applying a non-structural renewal coat. Periodic renewals are required to be carried out at specified frequency (scheduled response) or based upon

condition and performance of road surface (performance based) depending upon category of road, traffic and climatic conditions to improve the riding quality and reduce the rate of deterioration of the pavements.

5. PLANNING OF MAINTENANCE ACTIVITIES

5.1 All types of pavement maintenance need a comprehensive maintenance program. Following guidelines are to be considered in planning of routine, preventive and periodic maintenance activities.

The first step towards planning of maintenance operations is the evaluation of the existing pavement surface in terms of its physical condition as well as structural capacity. For this purpose, pavement condition surveys may be undertaken using manual or instruments by identifying type, location and magnitude of the distress as described in **Appendix-1**. The rating of pavement may be assigned as per the criteria given in **Tables 5.1** to **5.3** and determination of PCI for different classes of roads, are given in **Appendix-2**. Maintenance recommendations based on PCI value (0-100 scale) can be as per **Table 5.5**.

Table 5.1 Pavement Distress and Roughness Index Based Rating for Highways

Defects (type)	Range of Distress		
	Excellent to Good	Satisfactory to Fair	Poor to Fail
Cracking (%)	<5	5 to 10	>10
Ravelling (%)	<1	1 to 10	>10
Potholes (number)	Nil	1 to 2	>2
Patching (%)	<1	1 to 10	>10
Rut depth (mm)	<5	5 to 10	>10
Maximum Permissible Range of Roughness Index			
Surface Type	IRI (m/km)	RI (mm/km)	IRI (m/km)	RI (mm/km)	IRI (m/km)	RI (mm/km)
Bituminous Concrete, Stone Mastic Asphalt, Semi Dense Bituminous Concrete	<2.55	<1800	2.55 to 3.30	1800 to 2400	>3.30	>2400

Table 5.2 Pavement Distress and Roughness Index Based Rating for MDR(s) and Rural Roads

Defects (type)	Range of Distress (MDR and Rural Roads)		
	Excellent to Good	Satisfactory to Fair	Poor to Fail
Cracking (%)	< 10	10-20	>20
Ravelling (%)	<10	10-20	>20
Potholes (number)	Nil to 1	>1 to 5	>5
Patching (%)	<5	5-20	>20
Rut depth (mm)	<10	10 to 20	>20

Maximum Permissible Range of Roughness Index (MDR)						
Surface Type	IRI (m/km)	RI (mm/km)	IRI (m/km)	RI (mm/km)	IRI (m/km)	RI (mm/km)
Surface Dressing	<4.03	<3000	4.03-4.98	3000-3800	>4.98	>3800
Open graded premix Carpet	<3.79	<2800	3.79-4.62	2800-3500	>4.62	>3500
Mix Seal Surfacing	<3.55	<2600	3.55-4.27	2600-3200	>4.27	>3200
Semi Dense Bituminous Concrete	<3.05	<2200	3.05-4.03	2200-3000	>4.03	>3000
Bituminous Concrete	<2.81	<2000	2.81-3.55	2000-2600	>3.55	>2600
Maximum Permissible Range of Roughness Index (Rural Roads)						
Surface Type	IRI (m/km)	RI (mm/km)	IRI (m/km)	RI (mm/km)	IRI (m/km)	RI (mm/km)
Surface Dressing	<4.27	<3200	4.27-4.98	3200-3800	>4.98	>3800
Open graded premix Carpet	<4.03	<3000	4.03-4.62	3000-3500	>4.62	>3500
Mix Seal Surfacing	<3.79	<2800	3.79-4.27	2800-3200	>4.27	>3200
Semi Dense Bituminous Concrete	<3.33	<2400	3.33-4.03	2400-3000	>4.03	>3000

Table 5.3 Pavement Distress and Roughness Index Based Rating for Urban Roads

Defects (type)	Range of Distress		
	Excellent to Good	Satisfactory to Fair	Poor to Fail
Cracking (%)	<5	5 to15	>15
Ravelling (%)	<5	5 to 10	>10
Potholes (number)	Nil	1 to 3	>3
Patching (%)	<5	5 to10	>10
Rut depth (mm)	<5	5 to 10	>10

Maximum Permissible Range of Roughness Index						
Surface Type	IRI (m/km)	RI (mm/km)	IRI (m/km)	RI (mm/km)	IRI (m/km)	RI (mm/km)
Bituminous Concrete, Stone Mastic Asphalt, Semi Dense Bituminous Concrete	<2.55	<1800	2.55 to 3.30	1800-2400	>3.30	>2400

Note: *The defect type (%) and number of pothole per km or for the desired section length shall be calculated carriageway wise (considering all lanes/area of all lanes in one direction of traffic). IRI and Rut depth shall be taken as average value of all lanes in one direction of traffic. All data shall be analysed for 100 m to 1000 m length depending upon the analysis type (project level or network level).*

5.2 For the purpose of obtaining/assigning the overall condition rating, Pavement Condition Index (PCI) value based rating methodology in 0 to 100 scale has been proposed.

Present pavement condition can be quantified considering functional parameters influencing section's performance and can be quantified in terms of a Pavement Condition Index (PCI). The proposed PCI varies from 0 to 100 where 0 represent pavement in failed condition and 100

corresponds to pavement section in Excellent condition. Representation of different pavement condition corresponding to different values of PCI is shown in **Fig. 5.1**.

Fig. 5.1 Representation of PCI Scale

The functional parameters considered for the determination of Pavement Condition Index includes

1) Cracking Extent 2) Ravelling Extent 3) Patching Extent 4) Pothole Number

5) Rut Depth 6) International Roughness Index

Different steps involved in determination of PCI are depicted in **Fig. 5.2**.

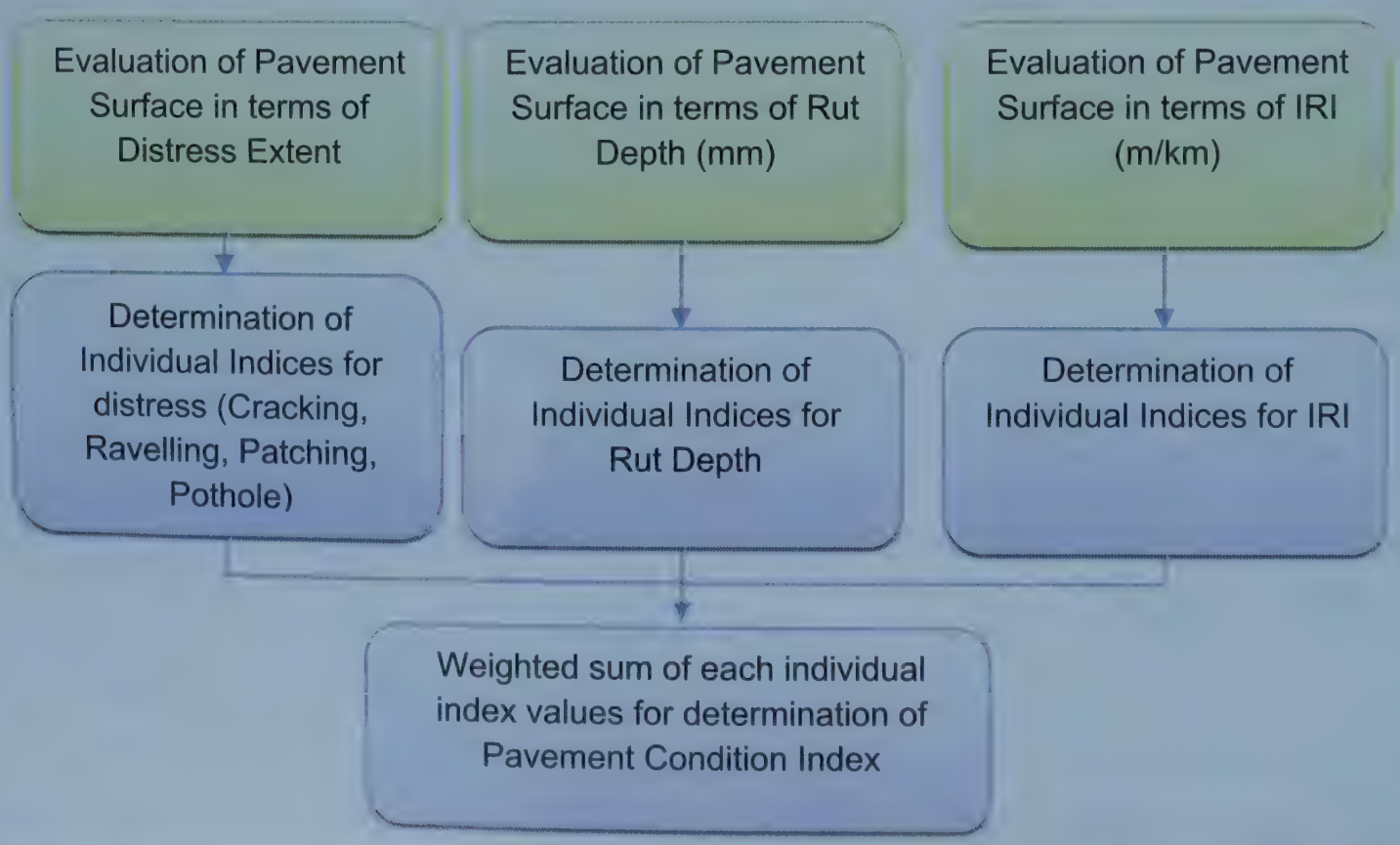

Evaluation of Pavement Surface in terms of Distress Extent
Evaluation of Pavement Surface in terms of Rut Depth (mm)
Evaluation of Pavement Surface in terms of IRI (m/km)
Determination of Individual Indices for distress (Cracking, Ravelling, Patching, Pothole)
Determination of Individual Indices for Rut Depth
Determination of Individual Indices for IRI
Weighted sum of each individual index values for determination of Pavement Condition Index

Fig. 5.2 Procedure for Determination of Overall Pavement Condition Index

The extent of the distress can be calculated as the area of pavement section affected by a particular distress using equation

$$\text{Extent} = \frac{\text{Surface Area of Pavement Section affected by a distress}}{\text{Total Surface area of Pavement Section}} \times 100 \quad (1)$$

Please note: "Surface area of Pavement Section" means total area of all lanes in a carriageway for 100 m to 1000 m section length depending upon the analysis type (project level or network level).

The number of potholes shall be calculated as per the procedure given below:

$$\text{No of Potholes} = \frac{\text{Surface Area of Pavement Section affected by potholes } (m^2)}{\text{Area of Pothole unit (i.e. 0.1 } m^2)} \times 100 \quad (2)$$

Example: If the total area of potholing in the selected road length is 0.5 m^2, then equivalent number of potholes shall be = 0.5/ 0.1, i.e. 5 potholes for PCI calculations.

After determination of all individual PCI values, the final value of pavement condition index can be determined using the weighted sum of each individual index values. The weightage for different functional parameters for calculation of PCI is presented in **Table 5.4**. The Flexible PCI Utility program (given in separate CD) can be used directly for calculation of PCI values based on the equations used for determination of PCI for different classes of roads, which are given in **Appendix-2**.

Table 5.4 Weightage for different Performance Measures

Distress Parameter	PCI Weightage
IRI	0.40
Pothole	0.16
Rut Depth	0.14
Cracking	0.12
Ravelling	0.10
Patch Work	0.08

The maintenance recommendations based on PCI value are given in **Table 5.5**.

Table 5.5 Maintenance Recommendations based on PCI value (0-100 scale)

Condition	Excellent to Good		Satisfactory to Fair		Poor to Fail	
	Excellent	Good	Satisfactory	Fair	Poor	Fail
PCI Rating	>90 to 100	>80 to 90	>60 to 80	>40 to 60	>20 to 40	0 to 20
Recommendations	Routine Maintenance	Preventive Maintenance	Renewal (as per section 9.5)	Minor Rehabilitation (based on Structural evaluation)	Major Rehabilitation/ Structural Overlay	Re-Construction

5.3 Necessary information about the routine maintenance requirement shall be readily available with the maintenance staff who are expected to have information on the physical condition of the road surface, periodically. However, for preventive and periodic renewal requirement or short

term/long term maintenance strategies, condition surveys are carried out at a fixed frequency. It is desirable that at least two condition surveys are conducted every year on each stretch, first before and the second after the monsoon in case of highways and urban roads. Minimum one condition survey is required for other roads, preferably after monsoon. It is also desirable that pavement condition surveys on all two lane undivided and above corridors shall be carried out using an instrumented method such as Network Survey Vehicle. For single lane and Intermediate lane roads, in the absence of appropriate instrumented survey methods, manual/visual surveys shall be carried out by a team of experienced engineers at a responsible level.

Based on the condition survey data, the causes for the development of various distresses/ defects shall be examined in detail as described in Section 7 and a decision shall be taken for an appropriate maintenance activity. Type of maintenance activity to be undertaken shall depend upon pavement condition index as per **Table 5.5**.

Where severity of distress on the pavement has reached the extensive level which adversely affects the riding quality significantly and eventually smooth flow of traffic, these should be rectified by providing appropriate timely maintenance treatment. For other defects like minor cracking, and raveling, optimal maintenance strategy should be adopted considering various factors such as category of road, severity and extent of the distresses, budget availability, and a decision may have to be taken whether to go in for preventive maintenance treatment, application of periodic renewal or strengthening. In other words, the planning of the various maintenance operations should be correlated and looked upon as a total system rather than each activity being considered in isolation.

A plan has to be drawn for preventive maintenance or periodic renewals depending upon pavement condition index as given in **Table 5.5**. Once the overall maintenance plan has been drawn up, attention should be given to the proper organization and management aspects of the programme including deployment of various resources, i.e. men, materials and equipment, in an efficient manner. For each maintenance activity, the work at site should be carefully controlled so that the optimum output and quality are achieved.

Condition surveys may be undertaken/carried out manually or through an instrumented method as per the guidelines given in **Appendix -1**.

6. SYSTEM APPROACH TO PAVEMENT MAINTENANCE

6.1 The Pavement Maintenance Management System (PMMS) is a technical or operational methodology for managing or directing and controlling maintenance resources, in a scientific manner, for optimum benefits. It is a complex problem of matching resources, time, materials, labour, equipment, funds, design and, above all decision making, whereas, Pavement Management System (PMS) consists of a comprehensive, coordinated set of activities associated with the planning, design, construction maintenance, evaluation and research of pavements. A major objective of PMS is to assist the highway engineer in making consistent and cost effective decisions related to the construction, maintenance and rehabilitation of pavements.

6.2 The Pavement Maintenance Management System performs the following functions:

i) To identify projects in need of Maintenance & Rehabilitation (M&R) and to establish priorities

ii) Identification of the type of maintenance and/or rehabilitation required

iii) Requirement of type and timing of future M&R

iv) To minimize life-cycle costs or maximize benefits

v) To predict performance of pavement in future

6.3 The prime purpose of maintenance phase in a Pavement Management System is to determine the cost associated with providing various level-of-serviceability for any given pavement. This is an important feedback to planning, design and construction. The type and degree of maintenance can also influence the rate and serviceability loss for a pavement. It is reporting of maintenance practices and problems. Hence, maintenance management is primarily managing the resources to provide an agreed level-of-service.

7. TYPES OF PAVEMENT DISTRESS, THEIR IDENTIFICATION, SYMPTOMS, LOCATION, CAUSES, SEVERITY LEVELS AND TREATMENT

7.1 General

The types of defects in bituminous surfacing are grouped under four categories.

i) **Surface Defects:** These include fatty surfaces, smooth surface, streaking, and hungry surface

ii) **Cracks:** These include all types of cracks, viz., hair-line cracks, alligator cracks, longitudinal cracks, edge cracks, shrinkage cracks, and reflection cracks

iii) **Deformation:** These include rutting, corrugations, shoving including those caused by layer slippage, shallow depressions, settlements and upheavals etc.

iv) **Disintegration:** These include stripping, loss of aggregates, raveling, potholes, and edge breaking

The location and, severity of distress are important to select appropriate maintenance treatments, materials and technique.

7.2 Surface Defects

These are confined to surfacing and may be due to inappropriate quality and quantities of bitumen.

7.2.1 *Bleeding*

7.2.1.1 Symptoms

A surface having a thin film of excess or free bituminous binder on it, which creates a shiny, glass like reflecting surface tending to become soft in hot weather and slippery in cold and wet weather, eventually developing low skid resistance is referred to as bleeding or fatty bituminous surface.

7.2.1.2 Location

Generally such defect develops along the wheel path but sometimes these are restricted to isolated locations and specific lanes. Many a time, these defects are seen on entire carriageway.

7.2.1.3 Causes

Bleeding occurs in hot weather, when the bituminous binder after filling the available voids in compacted bituminous layer moves upward under traffic movement and collects as a thick film on the surface. The process is not reversible during cold weather, leading to permanent accumulation of binder on surface with passage of time making the surface fatty, slippery and skid prone. This can be caused by one or combination of the following factors:

i) Excessive binder in hot mix due to faulty mix design or lapses in quality control

ii) Lower voids in hot mix

iii) Use of softer grade binder

iv) Too heavy tack coat or prime coat

v) Loss of cover aggregates in surface dressing

vi) Excessive application of binder or non-uniform spreading of cover aggregate or flaky/ elongated cover aggregate in surface dressing

7.2.1.4 Severity Levels

A fatty surface may have different degree of severity depending upon reasons thereof. The severity of fatty surface and bleeding may be classified as low, medium and extensive. The isolated spots measuring less than 5 m^2 area in a lane km and restricted to only specific lane with total area less than 1% may be considered as bleeding/fatty surface of low severity. Sometimes bleeding/fatty surface is confined to entire lane along with wheel path. In case the area is in the range of 1 to 5%, it may be treated as fatty surface/ bleeding of medium severity. Extensive bleeding and fatty surface showing initiation of shoving shall be treated as fatty surface of "High Severity". **Photos 7.2.1 (a, b, c)** indicate low, medium and high severity level of bleeding and fatty surface respectively.

(a) Low severity **(b) Medium severity** **(c) High severity**

Photo 7.2.1 Bleeding

7.2.1.5 Treatment

a) **Low Severity:** Minor bleeding / low severity fatty surface can be corrected by applying heated coarse sand (passing 1.18 mm) to blot up excess bitumen in affected area followed by light rolling.

b) **Medium Severity:** Medium severity bleeding and fatty surface may be corrected by application of pre-coated chips; Passing 4.75 mm and retained over 1.18 mm using 1 % bitumen and generally applied in a single layer followed by light rolling. In case the layer of bleeding is less than 1 mm, treatment described for low severity would be sufficient.

c) **High Severity:** The affected portion shall be milled out and repaired with mix of desired quality. The milled material i.e. Recycled Asphalt Pavement (RAP) mixed with fresh aggregates may be laid followed by application of slurry seal/microsurfacing treatment. An open-graded premix carpet with low bitumen content can also be applied to absorb the excess binder. In the case of large areas of fatty surface, having irregularities, removal of the affected layer and replacing it with a layer having a properly designed mix, may be necessary.

7.2.2 *Smooth Surface (Low Skid Resistance Surface)*

7.2.2.1 Symptoms

A smooth surface has a very low skid resistance and becomes very slippery when it is wet. Such a condition invites safety hazards, especially on gradients, bends, and intersections, **Photo 7.2.2** indicate a smooth surface.

Photo 7.2.2 A View of Smooth Surface

7.2.2.2 Location

Smooth surface may be restricted to a lane/carriageway.

7.2.2.3 Causes

A primary cause for a smooth surface is the polishing of aggregates under traffic. Excessive binder can also contribute to formation of smooth surface.

7.2.2.4 Severity Levels

The severity level of smooth surface may be defined by skid number. A surface with skid number in the range of 30 to 40 indicates low severity smooth surface while skid number below 30 indicates high severity smooth surface. However, it is further recommended that the user shall consider the latest guidelines issued by MoRTH / IRC to determine the ranges for skid number.

7.2.2.5 Treatment

The rectification consists of resurfacing with a surface dressing course or a premix carpet or microsurfacing depending upon type of existing surface. Care should be taken to select aggregates which have proven non-polishing characteristics. The carpet can be an open graded mix. A slurry seal can also be used to impart anti-skid texture on a smooth surface.

7.2.3 *Streaking*

7.2.3.1 Symptoms

Streaking is characterized by the appearance of alternate lean and heavy lines of bitumen either in longitudinal direction or in transverse direction. **Photo 7.2.3** shows streaking.

Photo 7.2.3 Streaking of Bituminous Pavement

7.2.3.2 Location

Streaking may occur in a lane or carriageway.

7.2.3.3 Causes

Longitudinal streaking results when alternate longitudinal strips of surface contain different quantities of bitumen due to non-uniform application of bitumen across the surface. Some of the more common causes of streaking are mechanical faults, improper or poor adjustment and careless operation of bitumen distributors. These streaks can also be formed as a result of applying the bituminous binder at too low temperature; a temperature at which bitumen is not fluid enough to achieve uniform smooth flow from the nozzles on the spray bars. All these causes can result in transverse streaking also. Transverse streaking may also be caused by spurts in the bitumen spray from the distribution spray bar. These could be a result of mechanical faults in the distributor. Transverse streaking may result in corrugation in the pavement surface.

7.2.3.4 Severity Levels

Not applicable

7.2.3.5 Treatment

The satisfactory repair for longitudinal and transverse streaking is to remove the streaked surface and apply a new surface. It is always desirable to prevent longitudinal and transverse streaking than to correct it. Whenever mechanical equipment is used for spraying of bitumen, distributor should be carefully operated.

7.2.4 *Hungry Surface*

7.2.4.1 Symptoms

Hungry surface is characterized by the loss of fine aggregates from the surface or the appearance of dry surface with fine cracks; **Photos 7.2.4** indicate a dry and hungry surface.

Photo 7.2.4 View of Dry and Hungry Surface

7.2.4.2 Location

Hungry surface may be in full lane or carriageway.

7.2.4.3 Causes

One of the reasons for hungry surface is the use of less bitumen in the surfacing. Sometimes this condition may also appear due to use of absorptive aggregates in the surfacing.

7.2.4.4 Severity Levels

Not applicable

7.2.4.5 Treatment

Fog seal / liquid rejuvenating materials may be used for correction of dry and hungry surface. Slurry seal or microsurfacing may also be used as a repair measure, when applied in an average thickness of 2-4 mm.

7.3 Cracking

7.3.1 *General*

Cracking of bituminous surfacing is a common distress seen on majority of roads in India (with the passage of time). Cracks in bituminous surface are classified into various types depending upon severity. Immediate attention must be given for sealing of cracks, and prevention of their further widening as ingress of water through cracks is detrimental to pavement structure and performance of bituminous surfacing.

7.3.2 *Hairline Cracks*

7.3.2.1 Symptoms

Hairline cracks are present in narrow area and their width is less than one mm (**Photo 7.3.1**). Hairline cracks are generally isolated and normally these are not interconnected. These appear as short and fine cracks at close intervals on the surface. Many a time, such cracks disappear in hot summer.

Photo 7.3.1 Hairline Cracks

7.3.2.2 Location

These cracks may be at isolated places or in a lane/carriageway.

7.3.2.3 Causes

These cracks develop due to either insufficient bitumen content, excessive filler, improper compaction, oxidation of bitumen in surface or sometimes excessive moisture in granular layers. These may occur due to rolling of mix while it is still tender or due to excessive compaction.

7.3.2.4 Severity Levels

Not applicable

7.3.2.5 Treatment

These cracks may be treated by fog seal, application of liquid rejuvenating agents, slurry sealing and microsurfacing.

7.3.3 *Alligator and Map Cracking*

7.3.3.1 Symptoms

Alligator or map cracking is characterized as a series of interconnected cracks, having small irregular blocks in pavement surface which resemble the skin of an alligator. These cracks may be of different types depending upon extent and severity. The size of irregular shape blocks of cracks vary from less than 30 cm to more.

7.3.3.2 Location

Alligator or map cracks are normally appearing along the wheel path.

7.3.3.3 Causes

The causes of alligator cracking are many. These are developed due to one or more of the following reasons:

i) Excessive deflection of pavement surface normally at wheel path

ii) Inadequate pavement thickness

iii) Weakening of sub-grade or lower layers of the pavement due to ingress of excessive moisture to pavement and saturation

iv) Overloading of heavy commercial vehicles

v) Brittleness of binder due to ageing of binder and lowering of surface temperature due to weather conditions

vi) Stripping of underlying bituminous courses

7.3.3.4 Severity Level

Alligator cracking may be classified as low severity, medium severity and high severity. **(Photos 7.3.2-a,b,c)**

Low Severity: Low severity cracks are characterized by an area of cracking with very narrow cracks with almost no additional deterioration of the surface. The cracking is often isolated and many times, the cracking may not be interconnected to other areas and there is not much distortion. The depth and width of such cracks is in the range of 1 to 3 mm.

Medium Severity: Medium severity-cracking is characterized by interconnected cracks forming a small area similar to the skin of alligator. The cracks may have signs of slight spalling, with no pumping visible. The depth and width of such cracks lies between 3 to 6 mm.

(a) Low severity **(b) Medium severity** **(c) High severity**

Photo 7.3.2 Alligator Cracks

High Severity: High Severity alligator cracking is characterized by an area of moderate to severely spalled interconnected cracks creating a full pattern of cracking similar to skin of alligator. The width and depth in this case may be more than 6 mm. Pieces of bituminous surface may be loose or missing. The pumping of water and fine material below the pavement may be seen on the surface.

7.3.3.5 Treatment

In order to repair a pavement affected by alligator cracking, the main cause of the cracking should be determined. However, often the specific cause is fairly deep seated. Any investigation should involve digging a pit or coring the pavement to determine the pavement structural adequacy/ ability as well as determining whether or not subsurface moisture is a contributing factor. The repair needed is also based on the severity and extent of the cracking. Treatment of alligator cracking may be done by following the methods depending upon their severity.

a) Cracks sealing by bitumen emulsions

b) Crack sealing by rubberized and modified bitumen

c) Milling and surface recycling

In case of a pavement being structurally inadequate or weak, a properly designed overlay based on evaluation shall be provided

7.3.4 *Longitudinal Cracking*

7.3.4.1 Symptoms

Cracks that appear parallel to the centerline or along the road are called longitudinal cracks. These cracks are also sometimes source of onset of alligator cracking.

(a) Low severity **(b) Medium severity** **(c) High severity**

Photo 7.3.3 Longitudinal Cracking

7.3.4.2 Location

These cracks may appear at joints between two paving lanes or pavement and paved shoulders.

7.3.4.3 Causes

Longitudinal cracks in bituminous pavement are usually caused by alternate wetting and drying beneath the shoulder surface or by improper/weak joint between adjoining layers of pavement.

7.3.4.4 Severity Level

Severity of longitudinal cracks may be defined as low, medium and high. (**Photos 7.3.3: a, b** and **c**) The low severity is assigned to 1-3 mm wide and infrequent cracks medium severity is assigned to 3-6 mm wide cracks. High Severity is assigned to cracks, greater than 6 mm wide and are frequent (numerous).

7.3.4.5 Treatment

Treatment for longitudinal cracks depend upon the severity and extent of the cracking:

a) **Low and Medium Severity Cracks:** Crack sealing, preferably using rubberized bitumen

b) **High Severity Cracks:** Remove and replace the cracked pavement layer with fresh overlay.

7.3.5 *Transverse Cracks*

7.3.5.1 Symptoms

These cracks appear in the transverse directions or as interconnected cracks forming series of large blocks perpendicular to the direction of the road.

(a) Low severity **(b) Medium severity** **(c) High severity**

Photo 7.3.4 Transverse Cracks

7.3.5.2 Location

Transverse cracks may occur at isolated locations or in a lane/carriageway.

7.3.5.3 Causes

Transverse cracking may occur due to reflection of crack or joint in an underlying pavement layer. The low temperature brittleness or oxidation of bitumen and also structural failure at concrete base course are also causes of such cracking. Transverse cracks are usually formed due to shrinkage of bituminous mix on account of low temperature.

7.3.5.4 Severity level

Severity of transverse cracks may be defined as low, Medium and high (**Photos 7.3.4: a, b and c**). The low severity is assigned to 1-3 mm wide and infrequent cracks. Medium severity is assigned to 3-6 mm wide cracks. High Severity is assigned to cracks greater than 6 mm wide and are frequent (numerous).

7.3.5.5 Treatment

Transverse cracks may be treated using slurry seal or rubberized bitumen.

7.3.6 *Edge Cracking*

7.3.6.1 Symptoms

Edge cracking is defined as cracks which develop parallel to outer edge of the pavement.

7.3.6.2 Location

The location of edge cracking is normally 0.3 to 0.5 m inside of pavement edge.

(a) Low severity **(b) Medium severity** **(c) High severity**

Photo 7.3.5 Edge Cracking

7.3.6.3 Causes

The causes of edge cracking are many. Lack of lateral support from shoulder, settlement underlying the bituminous layers, inadequate surface drainage, shrinkage in sub-grade soil, inadequate pavement width near curves, inferior quality material in shoulders and thinner bituminous surface at edge of the pavement and wet sub-grade are some of the reasons for edge cracking.

7.3.6.4 Severity Level

The severity levels of edge cracks are low, medium and high (**Photos 7.3.5: a, b and c**). Low severity is with no breakup or loss of material, medium severity is with some breakup and loss of material (up to 10% of the affected length) while high severity is with considerable breakup and loss of material (more than 10% of the affected length).

7.3.6.5 Treatment

The following procedure/techniques are used for prevention or treatment of edge cracking:

) Promote good drainage along the edge of the road. Make sure that surface water will run to the nearby drain and not pond along the pavement edge.

i) Remove the dirty, poor draining shoulder material and replace it with a more permeable material.

ii) If truck traffic is substantial, place a structural overlay on the road surface of the order of 75-100 mm of hot mix to provide adequate support for heavier vehicle loads.

7.3.7 *Reflection Cracking*

7.3.7.1 Symptoms

Reflection cracks **(Photo 7.3.6)** are the sympathetic cracks that appear in the bituminous surfacing over joints and underneath cracked pavement. The pattern may be longitudinal, transverse, diagonal or block.

Photo 7.3.6 Reflection Cracking

7.3.7.2 Location

Reflection cracking occurs most frequently in bituminous overlays on cement concrete pavements, or on cement soil bases. They may also occur in overlays or surfacing on flexible pavements where cracks in the old existing pavement have not been properly rectified. Another condition under which reflection cracks can occur is when a pavement is widened. The location of the cracks will then be exactly on the junction between the old pavement and the widened portion. Reflection cracks may allow water to enter the underlying pavement and the sub grade and cause further damage in pavement.

7.3.7.3 Causes

Differential movement across the underlying crack or joint is responsible for development of reflection cracking. For joint reflection cracking, this is movement of the cement concrete slab beneath the bituminous surface because of the thermal and moisture changes.

7.3.7.4 Severity Levels

Not applicable

7.3.7.5 Treatment

The treatment, for all types of cracks discussed above, would depend on whether the pavement is structurally sound, or has become distorted or unsound. In case the pavement is structurally sound, then the cracks should be filled with a bituminous binder having a low viscosity so that it can be poured and worked into the cracks. Cut-back bitumen and emulsions are generally suitable. All loose materials are removed from the cracks with brooms and, if necessary, with compressed air jetting. The binder is poured with a pouring can and a hand squeegee is used to assist the penetration of the binder into the cracks. Light sanding of the cracks is then done to prevent traffic picking of the binder

If the cracks are wide enough a slurry seal or sand bituminous premix patching can be used to seal the cracks. If the cracks are fine and extend over large areas, a light cut-back or an emulsified bitumen (fog seal) can be broomed into the cracks and lightly sanded to prevent the picking up of the binder by the traffic. Stress Absorbing Membrane (SAM) or Stress Absorbing Membrane Interlayer (SAMI) may be used to seal reflection cracking and prevention of occurrence.

7.4 Deformation

Deformation may be restricted to one or more layers of bituminous courses or may extend to entire pavement and sub-grade. A change in the original shape of the pavement surface is known as deformation. It may be reflected in the form of slippage, rutting, corrugation, shoving, shallow depression and settlement.

7.4.1 *Slippage*

7.4.1.1 Symptoms

Slippage is the relative movement between the wearing course and the layer beneath the bituminous surface. It is characterized by the formation of crescent shaped cracks that point in the direction of the thrust of the wheels on the pavement surface. This does not mean that the cracks invariably point in the direction of the traffic. For example, if brakes are applied on a vehicle going down a hill, the thrust of the wheels will be pointing uphill. The cracks in this case will, therefore, point uphill.

(a) Low **(b) High**

Photo 7.4.1 Slippage of the Bituminous Wearing Coat

7.4.1.2 Location

Slippage of bituminous surface normally occurs along the wheel path of heavy vehicles.

7.4.1.3 Causes

Slippage is caused by unusual thrust of wheels in a specific direction due to omission or inadequacy of tack coat, lack of bond between the wearing coat and the lower layer caused by a layer of fine dust, moisture or both. Failure of bond between two layers due to excessive deflection of the pavement may also be responsible for slippage of wearing coat or successive layer.

7.4.1.4 Severity Level

Slippage may be classified as low severity and high severity slippage (**Photos 7.4.1: a and b**). In case, slippage is at isolated locations in a lane, it is classified as low severity slippage. In case, slippage is along the wheel path in entire lane or carriageway, it is classified as high severity slippage.

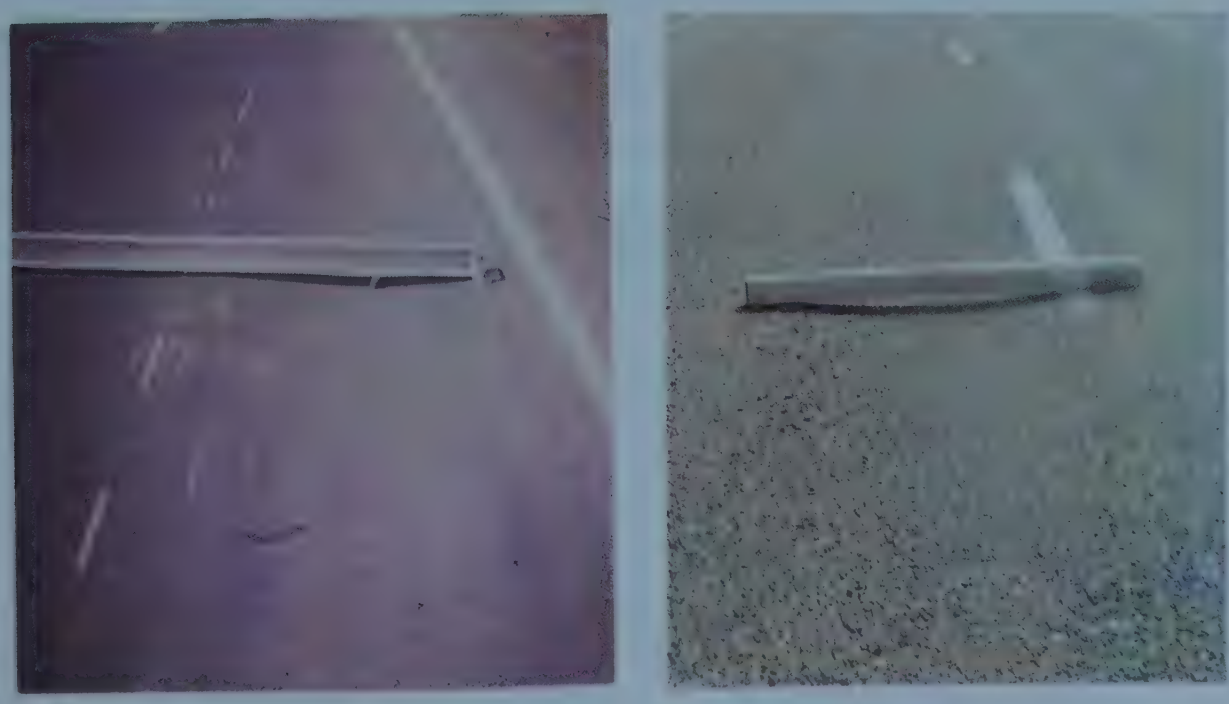
7.4.1.5 Treatment

Rectification consists of removing the surface layer around the area affected up to the point where good bond between the surfacing and the layer underneath exists and patching the area with premix material after a tack coat.

7.4.2 *Rutting*

7.4.2.1 Symptoms

Rutting is longitudinal depression or groove in the pavement along the wheel path. Rutting is categorized into three types and defined by the cause and layers in which rutting occurs, and it can be characterized by two components of the original (initial) pavement profile change, which are direct consequences of permanent deformation such as uplift and downward deformation.



(a) Low severity **(b) High severity**

Photo 7.4.2 Rutting in Bituminous Surface

7.4.2.2 Location

Rutting generally appears along the wheel path.

7.4.2.3 Causes

The causes of rutting are the following:

i) Heavy channelized traffic and overloading of vehicles

ii) Inadequate compaction of the mix at the surface or in the underlying bituminous courses during construction

iii) Improper mix design, lacking in stability to support the traffic

iv) Weak pavement due to poor sub grade and inadequate design

v) Use of soft bitumen or waxy bitumen

vi) Intrusion of sub grade clay into granular base course or use of plastic filler in GSB/WBM/WMM

7.4.2.4 Severity

Rutting may be classified as per the details given in **Table 5.1, 5.2** and **5.3** for different categories of roads.

7.4.2.5 Treatment

The rectification consists of filling of ruts with premix (open-graded or dense-graded) patching materials and compacting to the desired levels. The locations of depression are first marked on the surface and then limits are determined with a string line. After applying a suitable tack coat, the premix is spread and compacted.

7.4.3 *Corrugation*

7.4.3.1 Symptom

Corrugation is the formation of regular undulations (ripples) across the bituminous surface. These are usually shallow (about 25 mm) and are different from the larger depressions caused by weakness in the lower layers of the pavement or the sub-grade. The spacing of the waves is 2-3 m. The corrugations can be a source of discomfort during driving and can become a hazard if allowed to become severe. A view of corrugated surface is shown in **Photo 7.4.3**

Photo 7.4.3 Corrugation of Bituminous Surface

7.4.3.2 Location

Corrugations may occur near wheel path or in entire lane or carriageway.

7.4.3.3 Causes

Corrugations occur due to the following reasons:

i) Lack of stability in the mix (excessive binder, high proportion of fines, too round or too smooth textured coarse or fine aggregate, too soft binder)

ii) Oscillations set up by the vehicle springs can cause alternative valleys and ridges.

iii) Faulty laying of surface course

iv) Insufficient rolling/rolling a tender mix

v) Braking action of vehicles on grade especially near intersections

7.4.3.4 Severity

Not applicable

7.4.3.5 Treatment

If the surface is thin, the same is scarified; including some portions of the underlying base, and the scarified material is re-compacted. A new surfacing layer is then laid. Cutting of high spots with a blade with or without heating and addition of leveling course materials can also be resorted to. Spreading of sand bituminous premix with a drag spreader with its blade adjusted to just clear the high spots can also be an effective way to make up the corrugation. The area is then thoroughly rolled.

7.4.4 Shoving

7.4.4.1 Symptoms

Shoving is a form of plastic movement within the bituminous layers resulting in bulging of the pavement surface. **Photo 7.4.4** shown shoving of bituminous layers.

Photo 7.4.4 Shoving of Bituminous Surface

7.4.4.2 Location

Shoving occurs characteristically at points, where traffic starts and stops (intersections, bus-stops), on hills roads or where vehicles accelerate or brake on grades and on sharp curves. The first indication of shoving appears in the form of slippage cracks which are crescent shaped cracks, with the apex of the crack pointing in the direction of the shove. **Photo 7.4.4** shows shoving of bituminous layers. Shoving occur near the wheel path.

7.4.4.3 Causes

i) Lack of stability in the mix (excessive binder, high proportion of fines, soft binder) in the bituminous surface or base course.

ii) Lack of bond between bituminous surface and underlying layer

iii) Heavy traffic movement involving negotiation of curves and gradients

7.4.4.4 Severity level

Not applicable

7.4.4.5 Treatment

The rectification consists of removing the material in the affected area down to a firm base and laying a stable premix patch.

7.4.5 *Shallow Depression*

7.4.5.1 Symptoms

Shallow depressions are isolated low areas of limited size, dipping about 25 mm or more below the profile, where water will normally become stagnant. The shallow depressions may or may not be eventually accompanied by cracking of surface. These may also lead to further deterioration of the surface and cause discomfort and unsafe surface to traffic. A view of shallow depression in shown in **Photo 7.4.5**

Photo 7.4.5 Shallow Depression in Bituminous Surface

7.4.5.2 Location

Shallow depressions are generally restricted to wheel path/heavy traffic lanes.

7.4.5.3 Causes

Shallow depressions are caused by isolated settlement of lower pavement layers due to pockets of inadequately compacted sub grade or subsequent pavement layers.

7.4.5.4 Severity level

Not applicable

7.4.5.5 Treatment

Shallow depressions are made up by filling with premix materials, open graded or dense graded, and compacting to the desired profile as the surrounding pavement.

7.4.6 *Settlements and Upheaval*

7.4.6.1 Symptoms

Settlements and upheavals are characterized by relatively large deformations of the pavement compared to shallow depressions. These are dangerous to traffic and cause reduction in speed of traffic. These are generally followed by extensive cracks over the pavement surface in the affected region. Settlements and upheavals are shown in **Photo 7.4.6 (a) and (b)**, respectively.

Photo 7.4.6 (a) Settlement in Bituminous Surfacing

Photo 7.4.6 (b) Upheaval in Bituminous Surfacing

7.4.6.2 Location

Settlement may be along the wheel path or at isolated locations in a lane carriageway.

7.4.6.3 Causes

The following are the causes for settlements and upheavals in bituminous pavements:

i) Inadequate compaction of the fill at locations behind bridge abatements, over utility cuts, etc

ii) Excessive moisture in sub-grade and permeable layer of sub-base and base caused by capillary action or poor drainage

iii) Inadequate pavement thickness

7.4.6.4 Severity

Not Applicable

7.4.6.5 Treatment

If settlements and upheavals indicate any inherent weakness in the fill, it may be necessary to excavate the defective fill and do the embankment afresh under properly controlled conditions. Material having good drainage qualities should be preferred. Under-drains may become necessary in locations where lack of drainage has been identified as the cause of failure. Where the cause of deformation is inadequate pavement thickness, then properly designed pavement shall be provided.

7.5 Disintegration

There are some defects which if not rectified immediately, result in the disintegration of the pavement into small and loose fragments. Disintegration, if not arrested in the early stages, may necessitate complete reconstruction of the pavement.

7.5.1 *Stripping*

7.5.1.1 Symptoms

This defect is characterized by the separation of bitumen film from the surfaces of the aggregate particles, due to the presence of moisture. This may lead to loss of bond between bitumen and aggregate and subsequently to loss of cohesion in mixture. A view of stripped aggregate surface is shown in **Photo 7.5.1**

Photo 7.5.1 Stripping of Bituminous Surface

7.5.1.2 Location

Stripping is either localized or extended to lane or entire carriageway.

7.5.1.3 Causes

Stripping may be caused by the following reason:

) Use of hydrophilic aggregates.

i) Inadequate mix composition.

ii) Continuous contact of water with the coated aggregate.

v) Initial over heating of the binder or the aggregate or both.

v) Presence of dust or moisture on aggregate surface when it comes in contact with the bitumen.

vi) Occurrence of rain or dust storm immediately after construction

vii) Higher concentration of salt in soil and rain water

viii) Use of improper grade of bitumen

x) Ageing of the bitumen leading to the embrittlement of the binder film.

7.5.1.4 Severity

Not applicable

7.5.1.5 Treatment

n the case of surface dressing, hot coarse sand heated to at least 150°C and spread over the affected areas, may be used to replace the lost aggregates. After spreading, it should be rolled mmediately so that it will be seated into the bitumen. If aggregates are only partially whipped off, a liquid seal may be the solution. In other cases, the existing bituminous mix should be removed and a fresh one laid. As a precautionary measure, a suitable anti stripping agent should be added to the bitumen, at the time of construction. Rejuvenating sealants, slurry seal or microsurfacing can be used to treat stripped surface.

7.5.2 *Ravelling*

7.5.2.1 Symptoms

Ravelling is defined as progressive separation and dissociation of fine aggregate particles and binder from the bituminous surface. Normally, fine aggregates wears away first followed by coarse aggregates. The raveling process generally starts from the surface downward or from the edge inward. Pavement surface lead to rough and jagged appearance after occurrence of raveling. Raveling differs from fretting that it involves plucking out of surface aggregate by traffic without loss of cohesion.

7.5.2.2 Location

Raveling may occur on any part of a lane or carriageway.

7.5.2.3 Causes

Ravelling is likely to occur on a surface due to one or more of following reasons:

i) Inadequate bitumen content in a mix

ii) Overheating of bitumen during mixing process

iii) Inadequate compaction during construction

iv) Stripping of bitumen from aggregate due to water at interface

v) Construction during cold and wet weather

vi) Use of inferior quality aggregate prone to fracture, crushing and opening of new faces.

vii) Use of absorptive aggregates

viii) Excessive ageing of binder

ix) Lack of performance related contract specifications

x) Improper filler / bitumen ratio

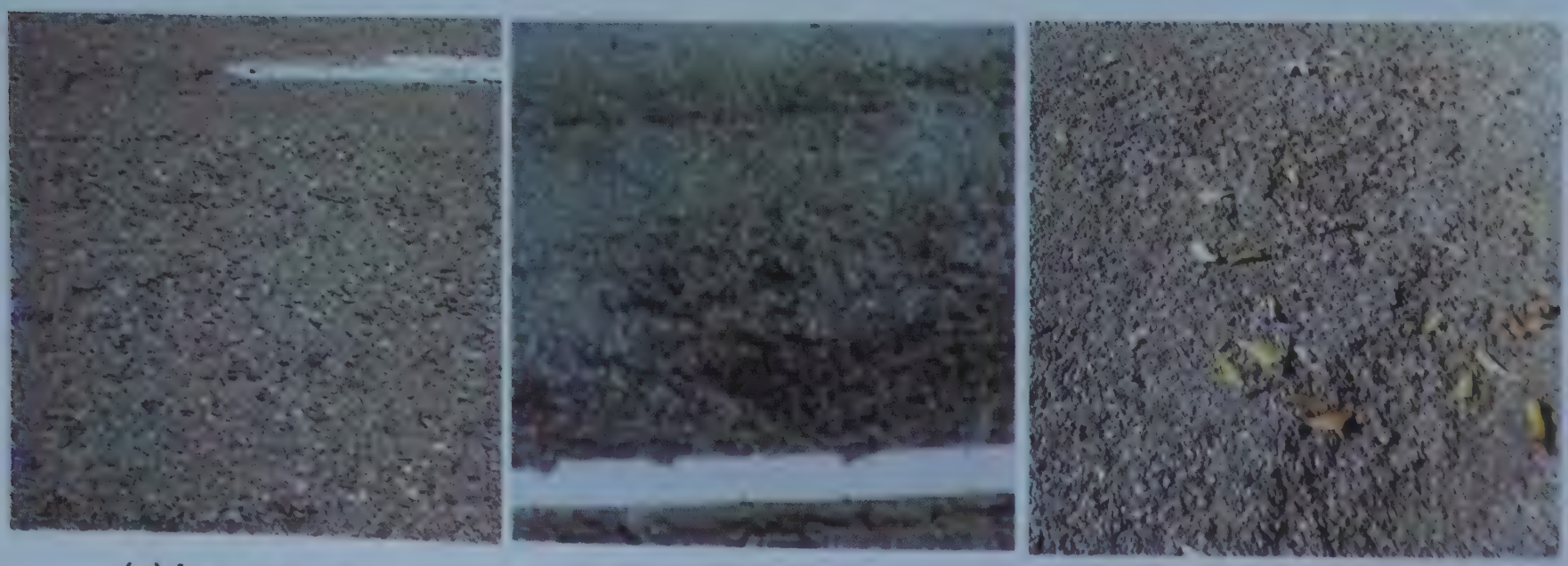
xi) High intensity hydrostatic pressure due to combined effects of traffic and water.

xii) Development of inclement weather (moisture, freezing) immediately after construction.

xiii) Traffic stresses exceed breaking strength of mix

7.5.2.4 Severity Level

Ravelling may be classified to three severity levels, viz., low severity, medium severity and high severity (**Photos 7.5.2: a, b and c**). Low severity is when some loss of fines is associated with initial stage of binder wearing out, medium is when loose particles exist with some loss having binder wearing out to a rough surface and high severity is when surface is too rough with loss of aggregates.



(a) Low severity **(b) Medium severity** **(c) High severity**

Photo 7.5.2 View of Ravelling

7.5.2.5 Treatment

The treatment of raveled surface shall depend upon severity of Raveling.

a) **Low severity raveling:** The low severity raveling may be corrected by application of fog seal, sand seal or seal coat, slurry seal and microsurfacing.

b) **Medium severity raveling:** This may be corrected by application of seal coat slurry seal or microsurfacing treatment in affected area.

c) **High severity raveling:** Depending upon condition of raveled surface and specification of existing surface. The high severity raveling may be corrected by single or multiple applications of liquid seal coat, slurry seal, microsurfacing and surfacing of thin overlay of appropriate mix specification like mix seal surfacing or open graded premix carpet.

7.5.3 Potholes

7.5.3.1 Symptoms

Potholes are bowl shaped cavities of varying sizes in a bituminous surface or extending into the binder/base course, caused by localized disintegration of material.

(a) Low severity **(b) Medium severity** **(c) High severity**

Photo 7.5.3 Potholes of Different Severity

7.5.3.2 Location

Potholes may occur in any part of road surface.

7.5.3.3 Causes

The most common cause of pothole formation is loss of adhesion in bituminous wearing coat due to the ingress of water into the pavement or due to higher voids in surface. The pavement gets weakened as a result of loss of cohesion, and under the action of traffic. The formation of pothole is aggravated due to use of plastic filler in granular base. If not attended to timely and properly, aggregates in the surface get progressively loosened to result in a pothole. Lack of proper bond between the bituminous surfacing and the underlying water bound Macadam base layer can also cause formation of potholes. Insufficient bitumen content in localized areas of the surfacing layer can also cause formation of potholes. A thin bituminous surface, which is unable to withstand the heavy traffic, can also cause formation of potholes, when associated with improper or inadequate camber. In dense-graded mixtures, potholes can be caused by too much fines or too few fines.

7.5.3.4 *Pothole unit*

The extent of potholing can be expressed in terms of 'pothole units. Each pothole unit has a surface area of 0.1 m^2, i.e., approximately 300 mm in diameter and therefore can be adequately estimated by reference to a person's foot. For estimating maintenance requirements in HDM-4, the depth of a pothole unit has been assumed to be 100 mm i.e. a volume of 10 liters (Ref: Manual of HDM-4, Volume 6). Therefore, number of potholes shall be estimated based on 'pothole unit' with surface area of 0.1 m^2.

7.5.3.5 Treatment

The rectification consists of filling potholes with open graded or dense graded premix. Potholes can be repaired by various methods

(i) Mixes (cold mixed/hot mixed) for immediate use

(ii) Storable cold mixes (cutback/emulsion Based)

(iii) Readymixes

(iv) Cold mixes by Patching machines

7.5.4 *Patch/Patch Deterioration*

7.5.4.1 Symptoms

Patching is the process of repairing damaged or excavated areas of bituminous pavement. To stop further degradation and expensive pavement repairs, potholes and other pavement damage should be fixed as soon as feasible. If a repair is not applied promptly, water may seep into the sub grade and lead to more serious pavement problems.

7.5.4.2 Severity Levels

Distresses in the patched area affect the severity level of the patch. Also, any distress in the boundary of the patch is included in rating the patch.

The low severity level of a patch is defined if it in good condition, performing satisfactorily and there is no loss of patching material. In medium severity level, patch has moderate severity distress of any type and in case of High Severity, patch is badly deteriorated and affects riding quality significantly **(Photo 7.5.3)**.

7.5.4.3 Treatment

Applications of sealant without aggregate are not to be recorded as patches. A full-depth or deep patch is a permanent repair; in contrast, a thin surface patch (less than 25 mm deep) is typically only temporary. There are several choices for repairing, including hot mixes bituminous emulsion mixes, stockpile patching mixes, and bespoke patching mixes with special combinations of aggregate and modified binders.

Full-depth patching involves the removal of the whole pavement surface layer, regardless of thickness, over the repairing region. Deep patching is the removal of 100 mm or more of the pavement surface course appropriate for bituminous pavements.

7.5.5 *Edge -Breaking*

7.5.5.1 Symptoms

A common defect in bituminous surface is edge breaking wherein the edge of the bituminous surface gets broken in an irregular way. **Photo 7.5.4** shows this type of defect. In case distress in not attended in time, the surfacing may peel off in chunks at the edges.

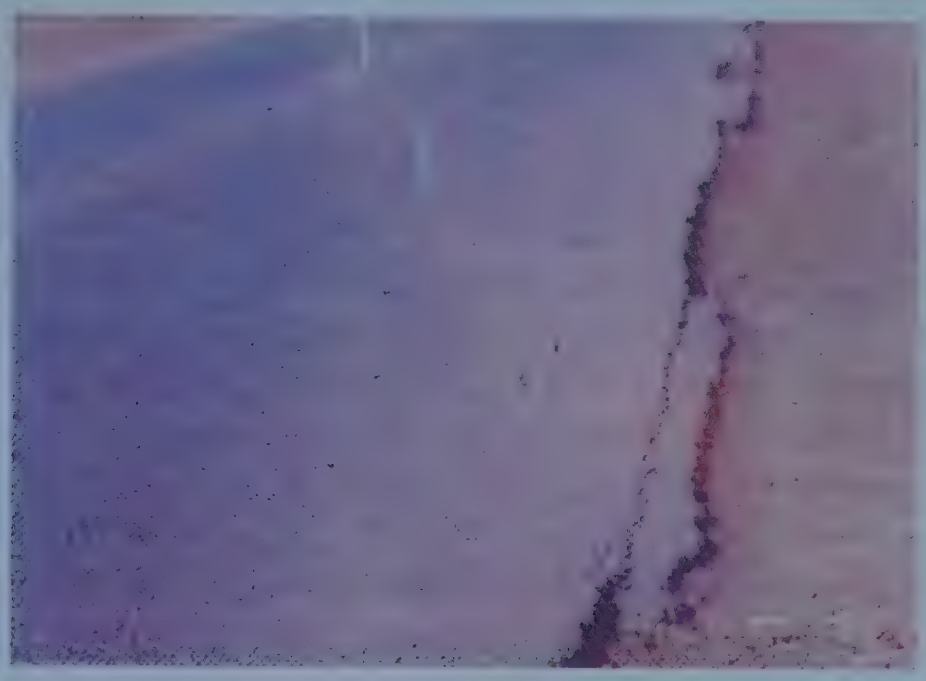


Photo 7.5.4 Edge Break-up

7.5.5.2 Location

Distress is restricted to edges upto 30 cm from edge.

7.5.5.3 Causes

The following are the causes for edge breaking:

- Infiltration of water which makes the foundation layers weak causing the pavement edges to break
- Worn out shoulders resulting in insufficient side support to the pavement
- Inadequate strength at the edge of the pavement due to inadequate compaction
- Lower layer of pavement being wider than upper layers
- Too narrow width

7.5.5.4 Severity

Not applicable

7.5.5.5 Treatment

The shoulder and the pavement materials in the affected area should be entirely removed to a regular section with vertical sides. The pavement and the shoulders should be built up simultaneously with thorough compaction. A bituminous surface similar to that in the adjacent reach should be laid. The shoulder should have adequate slope to drain away water. A slope one per cent steeper than the camber of the bituminous surface should be provided for earthen

shoulders. In order to prevent the edges from getting broken again, the maintenance operations should include periodic inspection of the shoulder condition and replacement of worn out shoulder material with adequate compaction. In sandy areas where the soil is likely to be eroded by wind and rain, it may be advantageous to have brick paving at least for some width to protect the edges. Surface and subsurface drainage, wherever deficient, should be improved.

8. PREVENTIVE MAINTENANCE

8.1 Introduction

Delays in maintenance increase the severity of distress in pavement leading to higher maintenance expenditure. Preventive maintenance is a planned maintenance activity, which decreases rate of surface deterioration and extend service life of bituminous pavement. It is a planned strategy of maintenance activity for cost-effective treatment of existing roads and its appurtenances. The preventive maintenance activity preserves the system, prevents future deterioration and improves the functional condition of the system without contribution to load carrying capacity of pavement. Such treatments are cost effective, if provided on a pavement in fair to good condition. The placement of right preventive maintenance treatment at the right time saves pavement from leading to poor condition (**Table 5.1 to 5.3**), where rehabilitation and reconstruction would be inevitable as far more costly.

8.2 Selection of preventive maintenance treatment

8.2.1 Preventive maintenance treatments shall be selected based upon the condition of existing pavement. The cracking, rutting, riding quality, climate and traffic are given due consideration in selection of preventive maintenance treatments. The concept of preventive maintenance stipulates that deterioration modes can be anticipated and at least partially mitigated before their occurrence. This provides following long term solutions.

- Improved level of service resulting from improved pavement performance
- Delayed need for rehabilitation and reconstruction
- Life cycle cost saving

8.2.2 For preventive maintenance applications, the following guidelines must be considered:

- Existing distress to be treated
- Anticipated distress to be delayed or prevented
- Appropriate treatment for existing condition
- Timing of treatment for best results
- Maximizing performance while minimizing cost

8.2.3 A thin overlay may not be considered as a preventive maintenance, when it is applied to a distressed pavement in poor condition. Slurry seal/ microsurfacing may not be considered as preventive maintenance, when placed on an extensively cracked surface. A preventive maintenance strategy comprises following:

- Identification of causes of distress
- Measurement of distress
- Selection of appropriate treatment
- Timing of treatment

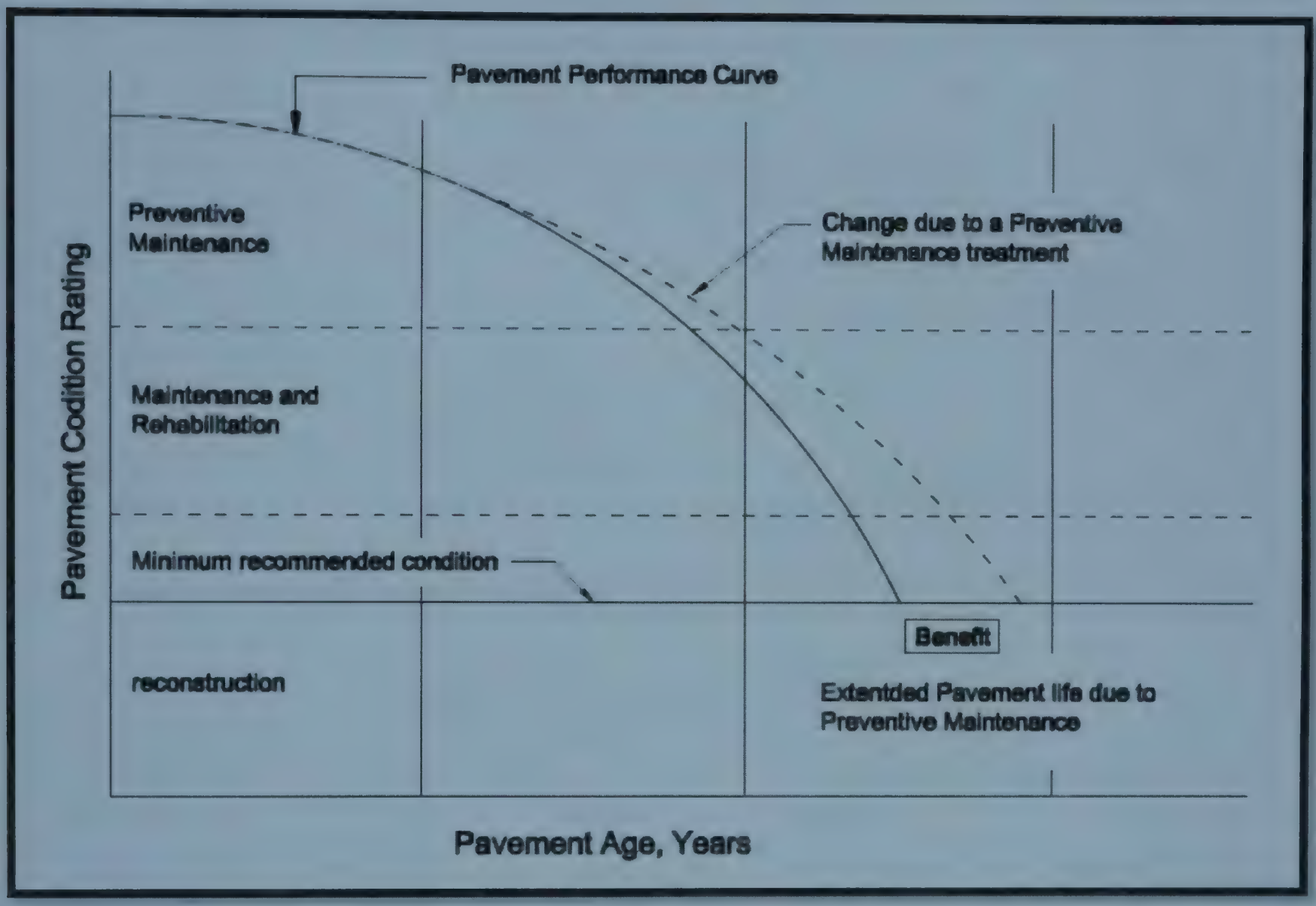


Fig. 8.1 Conceptual Illustration of Interventions

8.2.4 **Fig. 8.1** illustrates timing of preventive maintenance treatment, while selection of treatment depends upon type of distress causes, severity, climate and traffic. Preventive maintenance treatments shall be effective before the pavement condition index drops below 80. The type of treatment shall depend upon pavement condition rating as well as type and area of distress. The detailed warrants for choice of the treatment are given in **Tables 8.1 to 8.7**.

8.2.5 Suitable preventive maintenance treatment may be identified by following attributes.

- Purpose of treatment
- Applicability
  - Traffic
  - Environment
  - Surface condition

- Limitations
- Construction considerations
- Expected performance
- Cost effectiveness

8.2.6 The typical preventive maintenance treatments are given below.

- Crack sealing/ crack filling
- Fog seal
- Slurry seal
- Microsurfacing
- Surface Dressing
- Thin overlays (thickness less than 40 mm)
- Ultrathin friction courses

8.3 Warrants for Preventive Maintenance

The description and warrants for preventive maintenance treatments are given in **Table 8.1 to 8.7**

Table 8.1 Crack Filling or Crack Sealing

Crack Filling or Crack Sealing	Warrant			
	Climate	Traffic	Conditions Addressed	Limitations
These treatments are intended primarily to prevent the intrusion of moisture through existing cracks. Crack sealing refers to a sealing operation that addresses "working" cracks, i.e., those that open and close with changes in temperature. It typically implies high quality materials and good preparation. Crack filling is for cracks that undergo little movement. Sealants used are typically elastomers modified bituminous materials that soften upon heating and harden upon cooling.	Treatment can perform well in all climatic conditions.	Performance is not significantly affected by varying traffic.	■ Longitudinal cracking ■ Minor block cracking ■ Transverse cracking ■ No structural benefits, ■ Acceptable if the extent of cracking is minimal (little to no structural cracking).	■ Structural failure (i.e., extensive fatigue cracking or high severity rutting) ■ Extensive pavement deterioration, little remaining life
Site Restrictions	None.			
Construction Considerations	Placement should be done during warm and dry weather conditions. Proper crack cleaning is essential to a good bond and maximum performance.			

Table 8.2 Fog Seal

Description	Warrants			
	Climate	Traffic	Conditions Addressed	Limitations
Fog seals are placed primarily to seal the pavement, inhibit raveling rejuvenate hardened/ oxidized bitumen surface, and provide some pavement edge-shoulder delineation. Fog seals are very light applications of a diluted bitumen emulsion placed directly on the pavement surface with no aggregate. Typical application rates range from 0.23 to 0.45 kg. per m^2	Treatment performs well in all climatic conditions.	Increased traffic can increase surface wear	■ Longitudinal, ■ Transverse, and block cracking ■ Raveling/weathering (loose material must be removed) ■ Bitumen aging, oxidation and hardening ■ No structural improvement, but can help reduce moisture infiltration through fatigue cracks (if their severity is low), however, not recommended for heavily trafficked road corridors/ highways.	■ Structural failure (such as significant fatigue cracking) ■ Friction loss (M-H) ■ Thermal cracking (H)
Site Restrictions	Not appropriate for surfaces with poor skid resistance, as it will lower the skid resistance further.			
Construction Considerations	Typically, a slow-setting emulsion is used which requires time to "break," the pavement is sometimes closed for 2 hours for curing before being re-opened to traffic.			

Table 8.3 Slurry Seal

Characteristics	Warrants			
	Climate	Traffic	Conditions Addressed	Limitation
A mixture of well-graded aggregate (fine sand and mineral filler) and Bitumen emulsion that is spread over the entire pavement surface with either a squeegee or spreader box attached to the back of a truck. It is effective in sealing low-severity surface cracks, waterproofing the pavement surface, and improving skid resistance at speeds below 60 km/h. Thickness is generally less than 10 mm	Treatment performs effectively in all climatic conditions.	Performance in terms of surface wear is affected by increasing traffic. Accommodate the higher traffic volumes.	■ Transverse, longitudinal and block cracking (L) ■ Raveling/weathering (loose material must be removed) ■ Asphalt aging, oxidation and hardening ■ Friction loss ■ Moisture infiltration Adds no structural capacity; however, can temporarily seal cracks (if severity is low) or serve as a rut-filler (if the ruts are not severe and are stable)	■ Structural failure (such as significant fatigue cracking and deep rutting) ■ Thermal cracking
Site Restrictions	Pavement is often closed for several hours to allow the emulsion to cure.			
Construction Considerations	Surface must be clean. Aggregates must be clean, angular, durable, well-graded, and uniform (prefer 100% crushed). Avoid placement in hot weather (potential flushing problems) and premature opening to traffic. Do not place when freezing temperatures are expected.			

Table 8.4 Microsurfacing

Characteristics	Warrants			
	Climate	Traffic	Conditions Addressed	Limitation
Microsurfacing consists of a mixture of polymer-modified emulsified asphalt, mineral aggregate, mineral filler, water, and additives applied in a process similar to slurry seals. Used primarily to inhibit raveling and oxidation of the pavement surface. Also effective at improving surface friction and filling minor irregularities and wheel ruts (up to 40 mm)	Effective in all climate conditions.	Very successful on both low- and high-traffic volume	■ Longitudinal and transverse cracking (L) ■ Raveling/weathering (loose material must be removed) ■ Bleeding ■ Roughness ■ Friction loss ■ Moisture infiltration ■ Adds limited structural capacity. Temporarily seals fatigue cracks (if severity is low) and can serve as a rut-filler (if the existing ruts are stable)	■ Structural failure (i.e., extensive fatigue cracking) ■ Extensive pavement deterioration, little remaining life ■ Thermal cracks ■ Can accelerate the development of stripping in susceptible bituminous pavements
Site Restrictions	None.			
Construction Considerations	Avoid placement in hot weather if there is potential for flushing problems. Placement in cool weather can lead to early raveling, not to be placed when freezing temperatures are expected.			

Table 8.5 Surface Dressing

Description	Warrants			
	Climate	Traffic	Conditions Addressed	Limitation
Bitumen emulsion is applied directly to the pavement surface (1.2 to 1.7 kg/m^2) followed by the application of aggregate chips (0.004 to 0.015 cum/m^2 which are then immediately rolled to imbed chips. Application rates depend upon aggregate gradation and maximum size. Treatment seals pavement surface and improves friction.	Treatment performs well in all climatic conditions.	With proper design and placement, chip seals can perform well on high-volume roads. However, use is primarily limited to lower-speed, lower volume roads.	■ Longitudinal, transverse and block cracking ■ Raveling / weathering (loose surface material must be removed) ■ Friction loss ■ Roughness ■ Bleeding ■ Moisture infiltration ■ Adds almost no structural capacity. However, effective at sealing fatigue cracks in comparison with other treatments.	■ Structural failure (i.e., extensive fatigue cracking and/or deep rutting) ■ Thermal cracking (H) ■ Extensive pavement deterioration, little or no remaining life ■ Can accelerate the development of stripping in susceptible bituminous pavements
Site Restrictions	High-speed, high-volume roadways are often avoided, although a number of approaches are being used to extend the applicability of these treatments.			
Construction Considerations	Surface must be clean. Treatment should be placed during warm weather with chip spreader immediately behind asphalt distributor and rollers close behind the spreader. Approximately 2 hours required before roadway may be re-opened to normal speed traffic. Brushing is usually required to remove loose chips.			

Table 8.6 Thin Hot-Mix/Cold Mix Bituminous Overlays

Description	Warrants			
	Climate	**Traffic**	**Conditions Addressed**	**Limitation**
Plant-mixed combinations of asphalt cement and aggregate applied to the pavement in Thicknesses between about 15 and 25 mm Dense-graded, open-graded, premix and stone matrix mixes are used	Treatment performs well in all climatic conditions.	Performance should not be affected by different traffic condition Thin overlays are not structural layers and as such should not be subjected to strain from loadings. Such layers may be subject to top down cracking under certain combinations of loadings, environmental conditions, and pavement structures.	■ Functional/Other ■ Longitudinal and transverse cracking ■ Raveling/weathering (loose surface material must be removed) ■ Friction loss ■ Roughness ■ Bleeding ■ Block cracking may perform better with additional milling) Structural Rutting (assumes rutting has stopped; requires use of separate rut-fill application)	■ Structural failure (i.e., fatigue cracking) ■ Extensive pavement deterioration, little remaining life ■ Thermal cracking
Site Restrictions	Edge-shoulder drop-off should be considered. Surface should be uniform to ensure uniform compaction.			
Construction Considerations	Surface must be clean. A tack coat prior to overlay placement will help improve the bond to the existing surface. Thin HMA overlays dissipate heat rapidly and, therefore, depend upon minimum specified mix placement temperatures and timely compaction.			

Table 8.7 Ultrathin Friction Courses

Description	Warrants			
	Climate	**Traffic**	**Conditions Addressed**	**Limitation**
Relatively new treatment and consists of a gap-graded, polymer modified 10 to 20 mm layer placed on a tack coat formed by the application of a heavy, polymer-modified bitumen emulsion. Treatment effectively addresses minor surface distresses and increases surface friction.	Treatment should perform well in all climatic conditions	Capable of withstanding high ADT volumes and truck traffic better than other thin treatments	■ Longitudinal, transverse and block cracking. Higher severities can be addressed with cold milling. ■ Raveling/weathering (loose surface material must be removed) ■ Friction loss ■ Roughness ■ Bleeding ■ Provides some increased capacity and retards fatigue cracking. Not suited for rutted pavements.	■ Structural failure (i.e., significant fatigue cracking and/or deep rutting) ■ Extensive pavement deterioration, little remaining life ■ Thermal cracking
Site Restrictions	Ultrathin overlays should only be placed on structurally sound pavements. Localized structural problems should be repaired prior to overlay application.			
Construction Considerations	Requires special paving equipment to place the mix.			

9. PERIODIC RENEWALS

9.1 Need and Importance of Periodic Renewals

Periodic renewals consist of the provision of a thin surfacing layer at regular intervals of time, so as to preserve the required serviceability level of the pavement surface and offset the wear and tear caused by traffic and weathering. Periodic renewals represent maintenance, which is needed to prevent deterioration of the pavement and to ensure that initial qualities are kept up for the future requirements of traffic during the design life of the pavement. Early detection and repair of noticeable distress/ defects can prevent a major damage of the surface.

9.2 Planning and Programming of Renewals

The general practice in the country is to finalize renewal programme on an annual basis. In order to decide renewal layer on the surface, the renewal programme for each section of a road should be decided well in advance. Once the programme is finalized, steps could be taken to secure the required allocations and start the preliminary field action such as mobilization of resources. While the nomenclature "Periodic Renewal" would imply the renewal treatment to be carried out at a fixed and pre decided frequency, it would neither be practicable nor desirable to follow implicitly of any specified frequency irrespective of the condition of the road surface proposed to be renewed. The most effective way to plan a renewal programme is to carry out periodic inspections of the road surface at suitable intervals. In addition, special inspections are also necessary before and after the rains so as to assess the need for pothole repair and patching and other remedial measures required to be carried out either in advance or together with the renewal treatment.

9.3 Identification of Stretches to be Renewed

The stretches of the road showing signs of distress such as hungry surface/hair-line cracking, Raveling etc., should invariably be included in the renewal programme. This would ensure that the surface of the road and the pavement structure do not deteriorate further. The stretches of the road which would be due for periodic renewal on the basis of the pavement condition index and periodicity should be inspected closely and decision whether to include these in the renewal programme or to postpone the renewal for a specified period should be taken depending upon the condition of the road surface. In cases, the nature of distress/failure seen on the road is severe and of considerable extent and the causes are deep-seated and where it is considered the pavement cannot be improved with renewal treatment, detailed investigations shall be carried out and special measures shall be undertaken for correcting the same.

9.4 Types of Renewal Treatments

The types of bituminous surfaces those can be adopted are surface dressing (one or two coats), thin premix carpet, mixed seal, stone matrix asphalt, hot/cold mix semi- dense and dense bituminous concrete. Microsurfacing in one layer or two layers can also be used for renewals. These surface have different life spans depending upon traffic and environmental conditions.

The specifications adopted for the renewal layer on a particular road would depend upon the type of the original surface and its condition at the time of renewal. Following standards/specifications may be referred for periodic renewals:

) IRC:14 "Recommended Practice for Open Graded Premix Carpet"

i) IRC:SP:78 "Specifications for Mix Seal Surfacing (MSS), Close Graded Premix Surfacing" (CGPS)

ii) IRC:SP:79 "Tentative Specifications for Stone Matrix Asphalt"

v) IRC:SP:81 "Tentative Specifications for Slurry Seal and Microsurfacing"

v) IRC:107 "Specifications for Bitumen Mastic Wearing Courses"

vi) IRC:110 "Standard Specifications and Code of Practice for Design and Construction of Surface Dressing"

vii) IRC:111 "Specifications for Dense Graded Bituminous Mixes"

The specification and the thickness of the renewal course should be such that, as far as possible he road surface is restored close to its original condition. For example, renewal over an original not mix bituminous concrete surface would have to be bituminous concrete.

9.5 Periodicity of Renewal

Based on the experience and condition indices given in **Table 5.1** to **5.3**, broad guidelines for he type and periodicity of renewals are given in **Table 9.1**. This may be utilized as a guide for working out annual renewal programme on different sections of roads.

Table 9.1 Suggested Renewal on Flexible Pavement

Road Category	PCI*	(Roughness Index, mm/km)	Suggested Treatment** (Thickness, mm)
NH	60-80	1800-2400	30-40 BC
SH	60-80	2000-2600	30 BC/30 SDBC
MDR, RR	60-80	3000-3800	SD/PC/MSS/SDBC (20-25)
Urban Road	60-80	2000-2600	30-40 BC/SDBC/2 Coat Micro Surfacing

** When the PCI value of road is rated as <80, it is recommended that a detailed investigation is carried out to assess he strengthening requirement, if any. In case, the pavement is found to be structurally adequate, then the periodic renewal will suffice.*

*** Wherever feasible, recycling of wearing course may be preferred*

The priority of renewal treatment may be decided based on rating assigned as explained in section 5.1, earlier. If there are 10 roads (say), with ratings from 60-80, the roads may be arranged based on the ascending order of condition rating and the periodic renewal shall be prioritized in the same order subject to budgetary allocations.

9.6 Rectification of Profile at the Time of Renewal

The camber and super elevation provided initially on a road tend to get flattened out due to raffic. Before the renewal of surface is done, the cross profile should be corrected by means of a suitable profile correction course/leveling course, which may be compatible with existing surface specification.

10. MATERIALS AND METHODS FOR RECTIFICATION OF DISTRESS ON BITUMINOUS SURFACE

10.1 General

The section 7 has dealt with the identification of the distress, measurement of distressed area, types of defect and their causes, and the maintenance measures to be taken up in each case. This section describes various materials required for maintenance methods, which are applicable to "Routine, Preventive and Periodic Maintenance". Routine maintenance is covered in section 7. Preventive type of maintenance activities are covered in section 8. Maintenance operations of periodic nature are described in section 9. Repair materials and methods discussed in this Section fall under three categories:

i) Rejuvenation

ii) Seal, and

iii) Patching

Rejuvenation of oxidized and hungry bituminous surface can be done by application of liquid bituminous materials. The seal coat is a thin application of bitumen, which shall be covered with fine aggregate/ sand. Seal coat may be premixed material or a spray application. Patching is an application of premixed bituminous mixture. Patching is done to fill potholes, correct shallow depressions, rutting and correct edge irregularities.

10.2 Bituminous Materials

10.2.1 *Paving Bitumen*

Paving Bitumen conforming to IS:73:2012 is recommended for road maintenance works, unless otherwise specified. Paving bitumen is classified into four grades based on viscosity, viz., VG-10, VG-20, VG-30 and VG-40.

10.2.2 *Cut-back Bitumen*

Cut-back bitumen of different grades is required for cold weather construction as well as maintenance under all-weather conditions. Medium curing cut-back bitumen MC-800 conforming to IS:217 is recommended for preparation of storable bituminous pothole/patching mix.

10.2.3 *Bitumen Emulsion*

Bitumen emulsion is a two-phase system consisting of bitumen, water and one or more additives to assist in formation and stabilization and to modify the properties of the emulsion. The bitumen is dispersed throughout the water phase in the form of discrete globules, typically 1.0 to 25 μm in diameter, which are held in suspension by electrostatic charges stabilized by an emulsifier. Bitumen emulsions conforming to IS: 8887 are recommended for various maintenance applications including preparation of cold mixes and patching mixes.

10.2.4 *Foamed Bitumen*

Foaming of bitumen is a means of reducing the binder viscosity and increasing the binder volume. Foam bitumen is produced in an expansion chamber in which cold water, between 1 and 5%

by weight of bitumen, is injected under pressure into hot bitumen to produce foam. Expansion ratio and half-life are two important properties of foam bitumen. The expansion ratio is defined as the ratio of the volume of foam produced to the volume of liquid bitumen injected. The life time of foam is expressed as the 'half-life, defined as the time after which the maximum volume of foam is reduced by a factor of two. It is measured in seconds. The foam bitumen is used for stabilization of recycled asphalt pavement.

10.2.5 *Modified Bitumen*

Modified bitumen is the binder whose properties have been modified by the use of polymers and rubbers. IRC:SP:53 and IS: 15462 specify different grades of modified bitumen for construction and maintenance of bituminous roads.

10.2.6 *Modified Emulsions*

Modified emulsions are defined as bitumen emulsions whose aqueous phase is generally modified by latex of the rubber. Sometimes, bitumen is also modified before emulsification. These emulsions are used for microsurfacing applications. The specification of modified emulsion for microsurfacing is given in IRC:SP:81.

10.2.7 *Rejuvenating Agents/Sealants*

Rejuvenating agents are used for restoration of physico - chemical properties of oxidized bitumen of dry and hungry surface or oxidized bitumen in recycled asphalt pavement. Sometimes, these rejuvenating agents are used as sealants. The viscosity value of these rejuvenating agents lies between 100-300 seconds at 60°C by Say bolt fural viscometer.

10.2.8 *Anti-Stripping Agents*

Anti-stripping agents are organic surfactants which are used to prevent stripping of bitumen from aggregate and to improve adhesion between wet aggregate and bitumen. Specification of anti-stripping agent are given in IS:14982.

10.2.9 *Warm Mix Additives*

A warm mix asphalt technology utilizes chemical additives that have little effect on rheological properties of the binder. These additives reduce mixing, laying and compaction temperature of bituminous mixes. The guidelines for warm mix asphalt are given in IRC:SP:101.

Following standards/specifications may be referred for various maintenance treatments.

i) IRC:SP:81 "Tentative Specifications for Slurry Seal and Microsurfacing"

ii) IRC:SP:100 "Use of Cold Mix Technology in Construction and Maintenance of Roads Using Bitumen Emulsions"

iii) IRC:SP:101 "Guidelines for Warm Mix Asphalt"

iv) IRC:116 "Specifications for Readymade Bituminous Pothole Patching Mix Using Cut-Back Bitumen"

11. TOOLS AND EQUIPMENT

11.1 General

Use of mechanized methods and techniques for carrying out various maintenance activities are recommended for achieving efficiency and quality in maintenance operations. Suitable tools, plants and equipment of appropriate capacity need to be deployed keeping in view the type and magnitude of the work and desired output. Proper maintenance and upkeep of all maintenance tools, plants and equipment is very important to ensure quality work. It is always advisable to follow equipment maintenance instructions and schedule as per manufacturer's specifications. Some of the tolls and equipment especially tend to develop inaccuracies and defects with usage and hence, their regular monitoring/checking and rectification is essential.

Crack filling, pothole filling and patching works form the major part of the bituminous surface maintenance. While the crack sealing is generally carried out by manual methods, pothole filling and patching can be efficiently carried out by mechanized methods.

11.2 Pothole Filling/Patching

There are two main elements of durable pothole filling/patching; the material and the repairs process. For every combination of these two factors, the cost effectiveness of the overall pothole filling/patching work will depend on material, labour and equipment costs and the quantity of the work. The most economical combination of materials and process to the extent possible should be adopted to produce long lasting and cost effective patch repairs.

11.3 Tools and Equipment for Pothole/Patch Repairs

For carrying out durable, long lasting and cost effective repairs of potholes and patches, the following tools and equipment are generally required:

i) Material truck (with hand tolls)

ii) Equipment truck

iii) Mechanical tool/equipment for pavement cutting and dressing

iv) Compaction device (vibratory walk behind roller or plate compactor)

v) Air compressor with pavement cutter

vi) Spot mix (preparing hot/cold asphalt mix in situ)

vii) Asphalt mix carrying and laying equipment

viii) Traffic control devices and equipment

ix) Mechanical brooms for highways and urban roads

11.4 Modern Mobile Mechanized Pothole Filling/Road Patching Technologies

For durable and cost effective pothole filling/road patching, innovative indigenous and imported mechanized road patching technologies are available. Most machines and techniques incorporate use of cold mixes, while some use infrared radiation technique for heating the road surface for use as patching material. The following are some of the widely used technologies for the purpose:

- Machine Mixed Spot Cold Mix and Patching Equipment
- Mobile Mechanized Maintenance Units
- Jet patching Velocity Spray Injection Technology

The deteriorated portion of the existing pavement adjoining the pothole should be cut and loose particles removed before patching of pothole.

A view of various machines is given in Photos 11.1 to 11.6

1. Tanks for storage of emulsion and water
2. Hoppers for storage of aggregate
3. Weighing System
4. Air Compressor
5. Mixing Unit
6. Sprayer
7. Control Panel
8. Pump

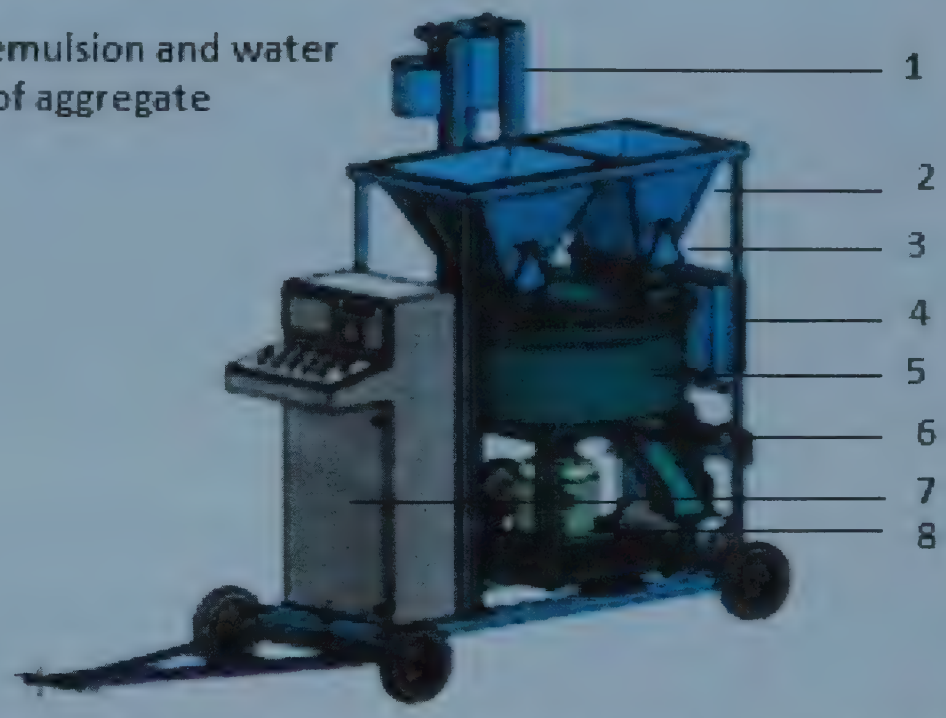


Photo 11.1 Pothole Repair Machine which can be mounted over a vehicle (CSIR-CRRI developed)

Photo 11.2 Vehicle Mounted Pothole Repair Machine (CSIR-CRRI developed)

Photo 11.3 View of Patrol Maintenance Machine used in Road Construction Department (RCD), Bihar

Photo 11.4 View of Mobile Highway Maintenance Van used in Haryana PWD

Photo 11.5 Spary Injection Type Pothole Repair Machine

Photo 11.6 Automated Pothole Repair Machine

These equipment and technologies are for general applications for pothole filling/patch repairs. Mobile mechanized maintenance units may be equipped for other applications also. For more specific applications or other maintenance treatments, various equipment and methods that are generally used are indicated in Section 9.4

12. ARRANGEMENTS FOR TRAFFIC AND SAFETY MEASURES DURING ROAD MAINTENANCE

12.1 Safety during Maintenance Work in Progress

12.1.1 The road construction and maintenance activities are an integral part of road network development and its preservation. Maintenance of roads is a normal recurring and periodic activity. During execution of maintenance activities, proper arrangements for safe operation and movement of normal traffic, maintenance workers and equipment in the work zones are most important. The road work zones are areas of conflict between normal operating traffic, workers, maintenance equipment and machines and work zone traffic. Care has to be taken to avoid/ remove conflicts between workers, maintenance equipment and traffic. As a good practice, it should be essential to prepare a Work Zone Traffic Management Plan (WTMP) to provide for reasonably protecting the workers and equipment. WTMP should provide for continuity of the movement for motorized vehicle, bicycle, and pedestrian traffic, transit operations, and access to properties and utilities.

It is equally important to ensure the safety of workers in Work Zones. Work zones present constantly changing conditions that are not expected by the road users, which create an even higher degree of vulnerability for the workers present near the roadway. A concurrent objective of the WTMP is the efficient construction and maintenance of the highway, as well as efficient resolution of traffic incidents, if any, likely to occur in the work zone. The WTMP, therefore, should facilitate the smooth and efficient flow of traffic as well as safe working environment.

12.1.2 Since maintenance operations involve considerable hardship, inconvenience and hazard to traffic and also hazard to maintenance workers, all possible precautions should be taken to make safe arrangements for traffic. These include erection of barriers, signs, red flags and lights. In order to promote road safety and efficiency by providing for the orderly movement of traffic on all roads during maintenance phases, road signs and other traffic management tools help in regulations of traffic and provide warning and guidance needed for safe, uniform and efficient operation.

12.1.3 A road sign should meet the following five basic requirements for their effectiveness:

a) Meet the requirement;

b) Command attention;

c) Convey a clear and simple meaning;

d) Command respect from road users; and

e) Give adequate time for response.

Design, placement, operation, maintenance, and uniformity are aspects that should be carefully considered in order to maximize the ability of a road sign to meet these basic requirements.

12.1.4 The maintenance related activities shall confine to half of the pavement width at a time leaving the other half for use by the traffic, to the extent possible. Otherwise, diversion roads may have to be constructed or the traffic diverted to some other alternative route with a proper information arrangement about the alternative. The maintenance operation itself can be conveniently confined to a small length at a time. The appropriate warning sign to be used such as "Men at Work" sign during working, or the "Narrow Road Ahead" sign if half of the road width is available for traffic, should also be displayed. During night, there should be adequate lighting with red reflectors/flashers/blinkers. All signs shall be in accordance with IRC:67 "Code of Practice for Road Signs". For further guidance and details on safety measures and traffic management during maintenance, IRC:SP:55 "Guidelines on Traffic Management in Work Zones" may be referred to.

12.2 Road Signs, Pavement Markings and other Traffic Control Devices

12.2.1 After completion of the maintenance work, the existing road markings, road signs etc. shall be restored to ensure safe and smooth movement of traffic. The maintenance staff shall keep the road authority informed of deficiencies, if any, observed in road signage, markings and other traffic control devices. Safety measures for necessary action to remove the deficiencies, is warranted to be identified for implementation therefore, as per relevant IRC Standard and Codes of Practice.

13. ORGANISATION AND MANAGEMENT

13.1 Maintenance of a road requires proper planning, programming and adequate tools, equipment, machinery and skilled workers/operators to carry out the required maintenance activities. There should be well equipped dedicated maintenance units or divisions within the organization in order to achieve the intended purpose in an effective and efficient manner. For primary roads, the nodal agency to identify the priorities and initiate action related to maintenance implementation is either MORTH or NHAI. In case of secondary and tertiary roads, the

maintenance is the responsibility of the State governments whereas urban roads are looked after by the local bodies. The traditional method of maintenance of roads by departmental work force or road gangs is being phased out and the road authorities are exploring alternative methods of implementing maintenance. Maintenance by contract is perceived as an efficient method. While it has been in practice since long and used successfully for implementing renewal programmes, the experience of road agencies with contracting out of routine maintenance has not been so successful and most road agencies have not yet switched over to routine maintenance contracts. This may be due to lack of standardization of contract forms and non-availability of maintenance contractors. Considering the size of the country's road network and road hierarchy, several forms and methods of implementing routine maintenance may be required to choose the one most suited to a road agency. Efforts are underway in this direction to standardize various types of maintenance contracts. In addition to this, availability and development of maintenance contractors requires to be addressed in a big way. During the transition period, the road agencies have to modernize the existing system to bring in efficiency, productivity and improved performance by introducing mechanization, mobile maintenance units, new and energy saving materials and institutionalizing dedicated maintenance set up. The effort should continue to be to move towards contracting out maintenance. This would require assured funding and effective supervision. Some model bidding documents for road maintenance have been developed for use of road agencies and these documents incorporate provisions for performance security, maintenance standards, performance criteria, simplified payment procedure, damages for non-performance, etc so as to ensure that the contractor is held accountable for the performance of maintenance.

13.2 Performance Based Maintenance Contracting (PBMC) is widely used for maintenance of roads. The contract specifies objective performance standards which define the road condition to which the roads are to be maintained and not allowed to fall below the specified level any time over the maintenance contract period. Monthly lump sum payments are made for maintenance on the basis of the accepted contract price. Monthly lump sum payments are subject to deductions if the required performance standard is not achieved. The deductions are effected as specified in the contract. Effective supervision is required to ensure that there is no deficiency in the performance of maintenance and condition of the roads and road assets included in the contract is maintained to the specified level.

13.3 For routine maintenance of low volume roads use of labor based and semi-mechanized methods are generally preferred. As the traffic increases, the level of mechanization should also increase for carrying out maintenance efficiently. For maintenance of roads carrying high volumes of traffic, machine based methods and technologies capable of carrying out maintenance with speed and safety and causing minimum interruptions in movement of traffic are recommended.

13.4 Planning and scheduling of the maintenance operations should be given due importance. The annual renewal programme should be drawn up well in advance keeping in view the condition of the surface and any improvement work carried out recently or scheduled to be taken up in the near future. In case sufficient funds are not available for renewal works, the priority may be decided following the suggested criteria given in Section 9.5. This would enable the field engineers to plan and implement maintenance programmes in a rational manner and according to available budget.

METHODOLOGY FOR PAVEMENT CONDITION SURVEY

Pavement Condition Surveys

Pavement condition surveys can be broadly classified into manual methods and instrumented condition surveys. While manual methods are cumbersome, slow to perform and includes safety risks, automated surveys can be conducted at fairly high speed with greater level of precision. Manual survey also requires well trained surveyors for measurement of distress or defect values.

Manual Method (Not recommended for Highways and Urban Roads)

Physical distress is identified and a quantitative visual assessment of distress is made by a well experienced/ trained team of 3-4 persons while moving in a vehicle at a speed of 8-10 km/hr.

While recording the distresses the details for the following pavement surface distresses are visually noted and recorded in individual percentage for each km length in **Proforma 1**.

1. Cracking (Alligator or fatigue cracking, Longitudinal and transverse cracking) *
2. Bleeding
3. Depressions/Settlements
4. Pothole*
5. Patching*
6. Ravelling*

The Rut Depth values are recorded using a 3 m straight edge.*

**Used for calculation of PCI*

In project level based maintenance strategies more precise condition data may be required and hence actual measurements of all the above distresses need to be measured in smaller representative sections. In such cases, the required information with measurements may be collected from field and recorded in **Proforma 2.**

Instrumented Method

This method involves use of advanced laser and camera based system for recording of international roughness index, rut depth and pavement surface distresses from a moving vehicle. Examples are Automatic Road Survey System (ARSS)/Network Survey Vehicle (NSV), which have become popular to record and assess pavement surface automatically at highway speeds and recommended for expressways, highways and urban roads.

Guidelines for Selection of Appropriate Equipment for Pavement Condition Survey

A user can decide the appropriate method for assessment of pavement condition based on the type of the road network. The details are summarised in **Tables A1.1.**

Table A1.1 Evaluation of Pavement Surface Condition Parameters

Road Category	Roughness	Surface Distress	Rut Depth (mm)
Four Lane Divided or More	It is recommended that the roughness of the existing pavement shall be assessed in terms of Roughness Index (mm/km) or International Roughness Index (m/km) as per the procedure given in IRC:SP:16-2019 document.	ARSS/NSV	ARSS/NSV
Two Lane		ARSS/NSV	ARSS/NSV
Single/Intermediate Lane		ARSS/NSV or Visual Survey	ARSS/NSV or Manual using a 3 m straight edge

ARSS-Automatic Road Survey System; NSV-Network Survey Vehicle

A brief description of Automated Road Survey System (ARSS)/Network Survey Vehicle (NSV)

A typical ARSS/NSV shall be equipped with the following major equipment or based on better technology:

- Distance Measuring Instrument (DMI)
- Global Positioning System (GPS)-Real Time Differential Global Positioning System are used to capture longitude, latitude and altitude of the road assets.
- Roughness using Laser Profilometer (LP)-Two laser sensors installed at both ends of Laser Profilometer are used to collect road profile along left and right wheel paths of the road for the computation of Left IRI and Right IRI (IRI-International Roughness Index).
- Mean Profile Depth (MPD) using Laser Profilometer (LP)-High frequency laser sensors installed in Laser Profilometer are used to collect Mean Profile Depth (MPD) data for the assessment of pavement surface macro texture.
- Pavement Distress Measurement System (PDMS)-Survey systems installed with High Resolution Cameras; Laser based Crack Measurement System, LiDAR etc., provides automated collection of pavement surface images for quantification of pavement surface distresses.
- Road Inventory using Right-of-Way Video Imaging System (ROW-VIS)-Survey systems installed with one or more high resolution color cameras are used to collect right-of-way information.
- Rut measurement using Automatic Rut Measurement System (ARMS)-Survey systems installed with Multi–Point Laser Sensors, Laser spectrum based Rut Measurement System, Laser based Crack Measurement System, LiDAR etc. are used for measurement of rut depth.
- Geometry details using Geometry Measurement System (GMS)-These systems are equipped with inertial sensors such as inclinometer, gyroscope etc. to measure the geometric details of the road network.

Various parameters recorded by ARSS/NSV are presented in **Table A1.2**.

Table A1.2 Parameters recorded by ARSS/NSV

Parameter Recorded	Equipment /Technologies
Distance Measurement	Distance Measurement Instrument (DMI) connected to the wheel axle to provide distance and speed information.
Geographical Position and Geo Referencing	GPS equipped with the vehicle is capable of recording location coordinates of vehicle as well as geo reference important road assets.
Roughness and Texture	Roughness is measured in terms of IRI, from the longitudinal profile of the road generated with help of Class-1 Laser Profilometer and Texture as Mean Profile Depth (MPD)
Pavement Surface Distress	Pavement Distress Measurement System (PDMS) using High Resolution Camera, Laser Crack Measurement System, LiDAR etc.,
Road Inventory	Right-of-Way Video Imaging System (ROW-VIS) using High Resolution Color Camera or LiDAR
Rut measurement	Automatic Rut Measurement System (ARMS) using Multi–point Laser, Laser Rut Measurement System, Laser Crack Measurement System, LiDAR
Geometric Details	Geometric details like gradient, rise and fall, cross slope and horizontal curvature are measured with Geometry Measurement System (GMS), which is normally based on accelerometer and gyroscope sensors.

The use of this equipment for pavement surface condition assessment is recommended for two lanes and four lane divided and above corridors.

VISUAL SURFACE DISTRESS MEASUREMENT

Name of the Road:

Chainage of Test Section:

Type of Surface:

Carriageway Width (m):

Date of Observation:

Weather Condition:

Chainage From	Chainage To	Cracks* (%)	Patch Work* (%)	Potholes* (Nos)	Bleeding (%)	Depression (%)	Edge Breaking (%)	Ravelling* (%)	Shoving (%)	Rut Depth* (mm)	Drainage & Shoulder condition	Total

*Only these distress parameters will be used for calculation of PCI value

Name of Team Leader _____

Signature of Team Leader _____

MEASUREMENT OF SURFACE DISTRESS
(FLEXIBLE PAVEMENT SECTION)

Name and Number of the Road
Chainage of Test Section : Km.....to Km.....
Chainage of Sub-Section : Km .....to Km.....
Type of Surface :

Carriageway Width (m) :
Date of Observation:
Weather Condition :

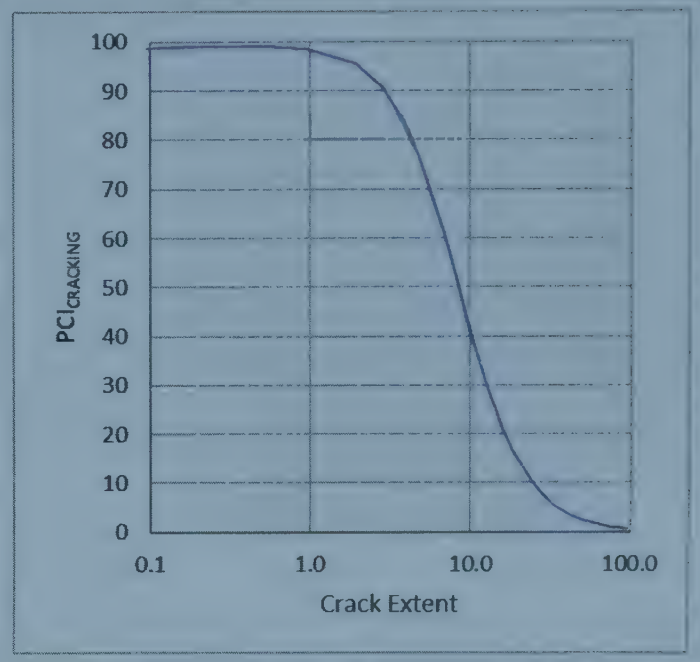
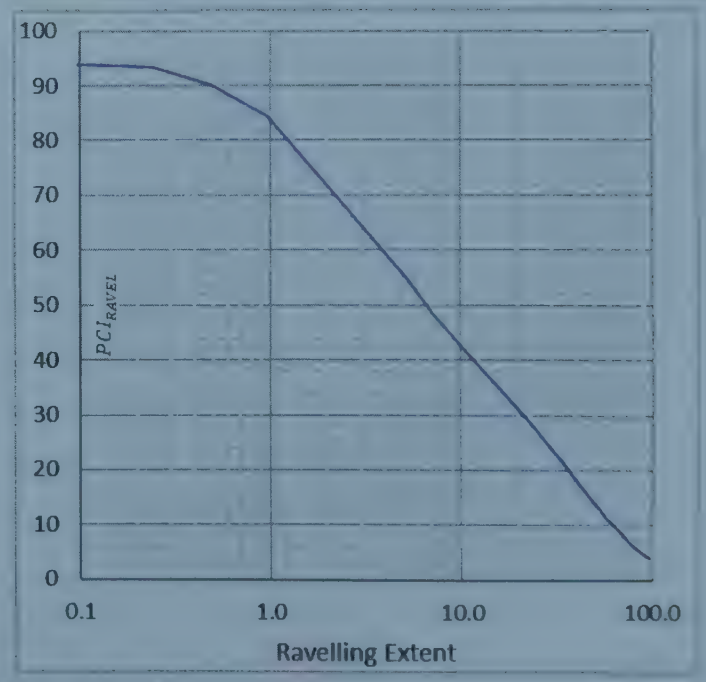
Cracks with Type*		Patch Work*		Potholes*			Bleeding		Depression/ Settlement		Edge Breaking		Ravelling*		Shoving		Rut Depth (mm)*	Drainage and Shoulder Condition
Size (m) (LxB)	Area (m^2)	Size (m) (LxB)	Area (m^2)	Size (mm) (LxB)	Area (mm^2)	Depth (mm)	Size (m) (LxB)	Area (m^2)	Size (m) (LxB)	Area (m^2)	Size (m) (LxB)	Area (m^2)	Size (m) (LxB)	Area (m^2)	Size (m) (LxB)	Area (m^2)		
*Only these distress parameters will be used for calculation of PCI value																		

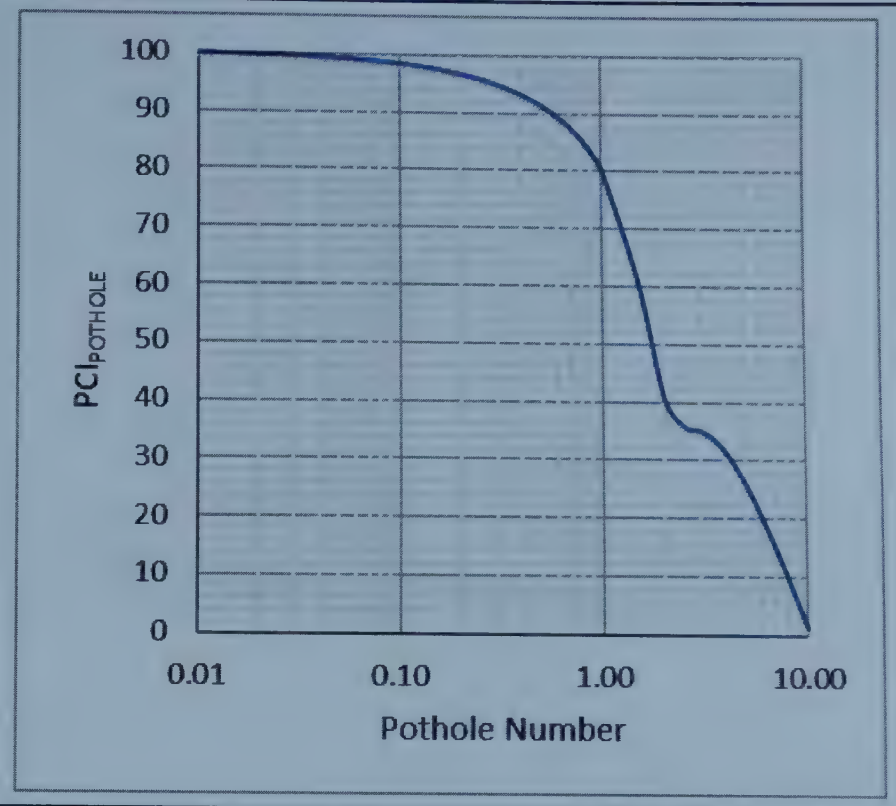
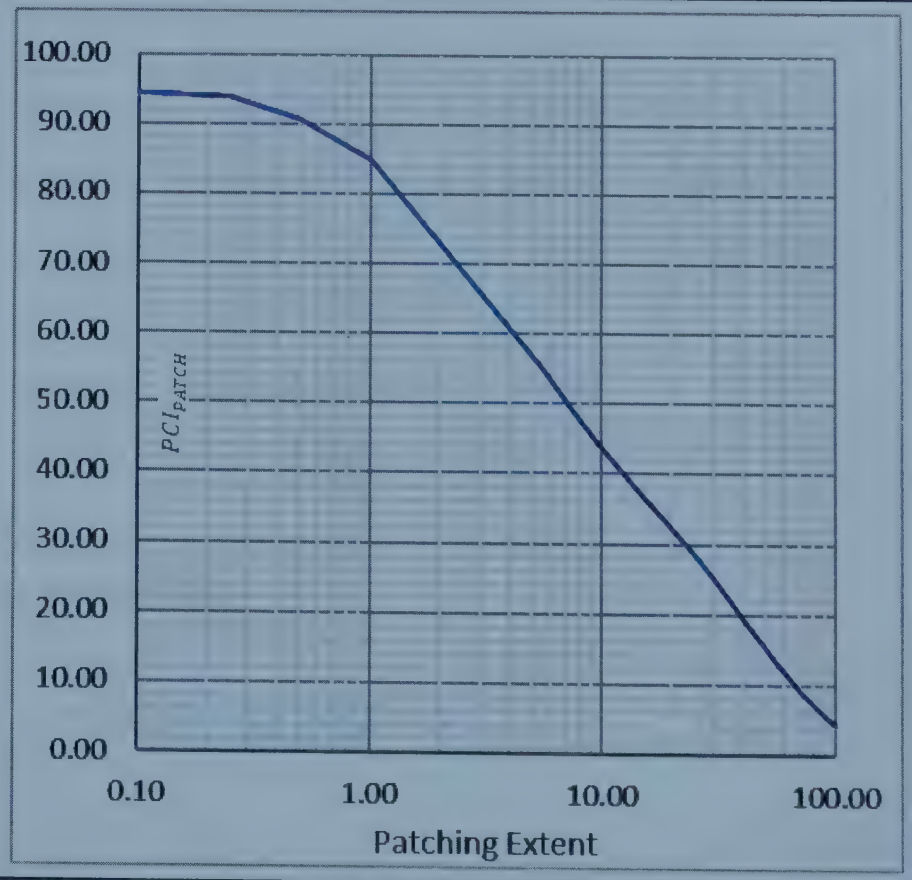
Name of Team Leader _____

Signature of Team Leader _____

DETERMINATION OF PCI FOR DIFFERENT CLASSES OF ROADS

Table A2.1 PCI based Ratings for Highways

Defects (Type)	Equations	Curve
Cracking (%)	$PCI_{CRACKING} = \frac{7231}{CE^2 - 0.737 \times CE + 73.09}$ Where CE=Crack Extent	
Ravelling (%)	$PCI_{RAVEL} = 52.92 * e^{-0.02525*RE} + 44.1 * e^{-0.2899*RE}$ Where RE=Ravelling Extent	

Defects (Type)	Equations	Curve
Pothole (Number)	$PCI_{POTHOLE} = \frac{-80.32 \times PN^3 + 1129 \times PN^2 - 3524 \times PN + 3566}{PN^3 + 5.791 \times PN^2 - 28.67 \times PN + 35.72}$ Where PN = Pothole number	
Patching (%)	$PCI_{PATCH} = 52.92 * e^{-0.02525 * PaE} + 44.1 * e^{-0.2899 * PaE}$ Where PE = Patch Extent	

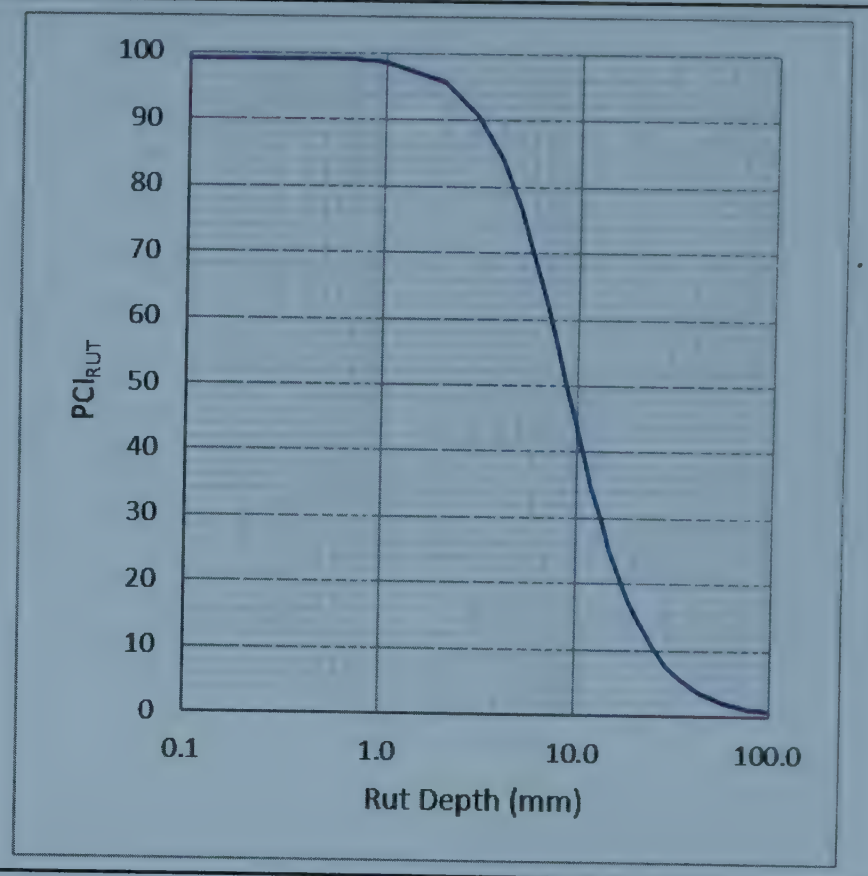
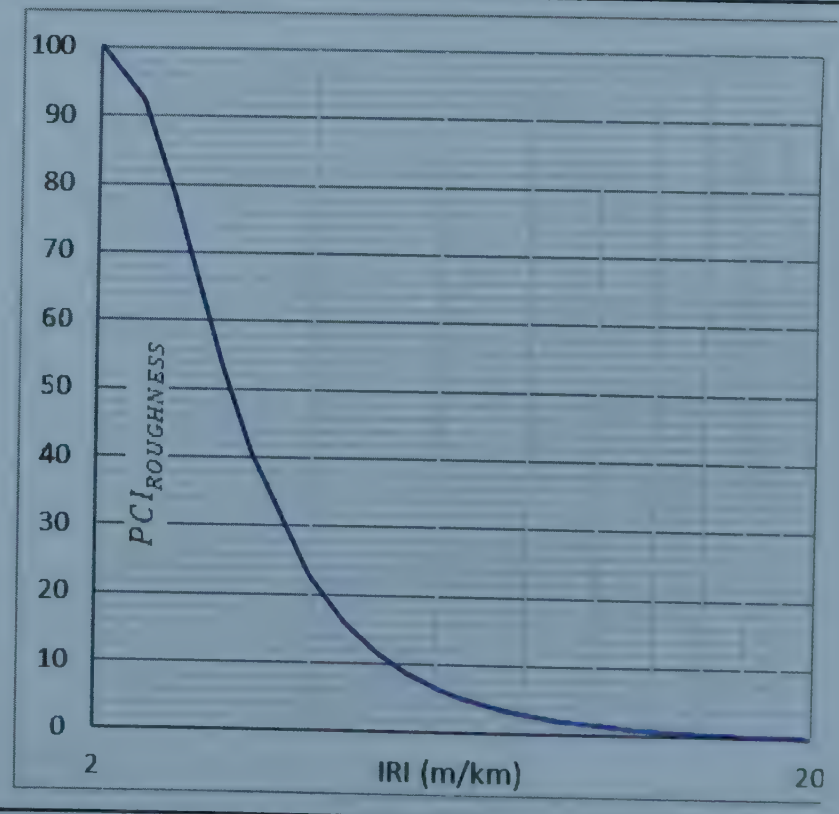
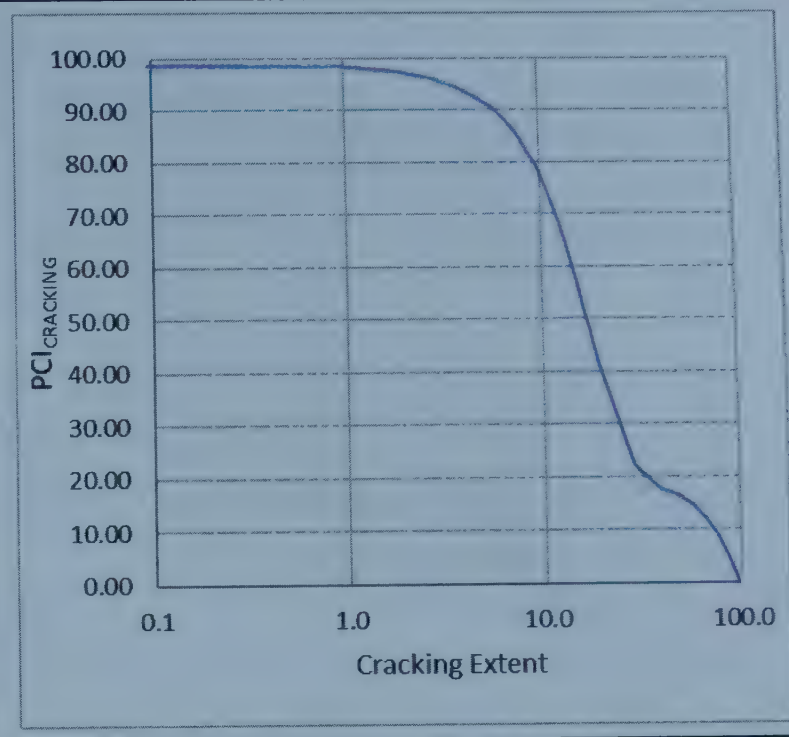
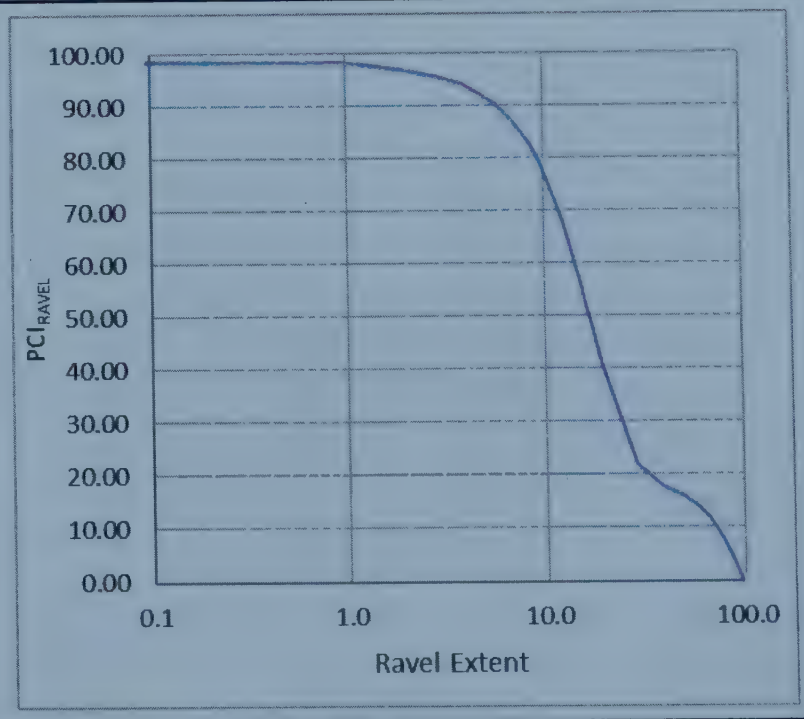
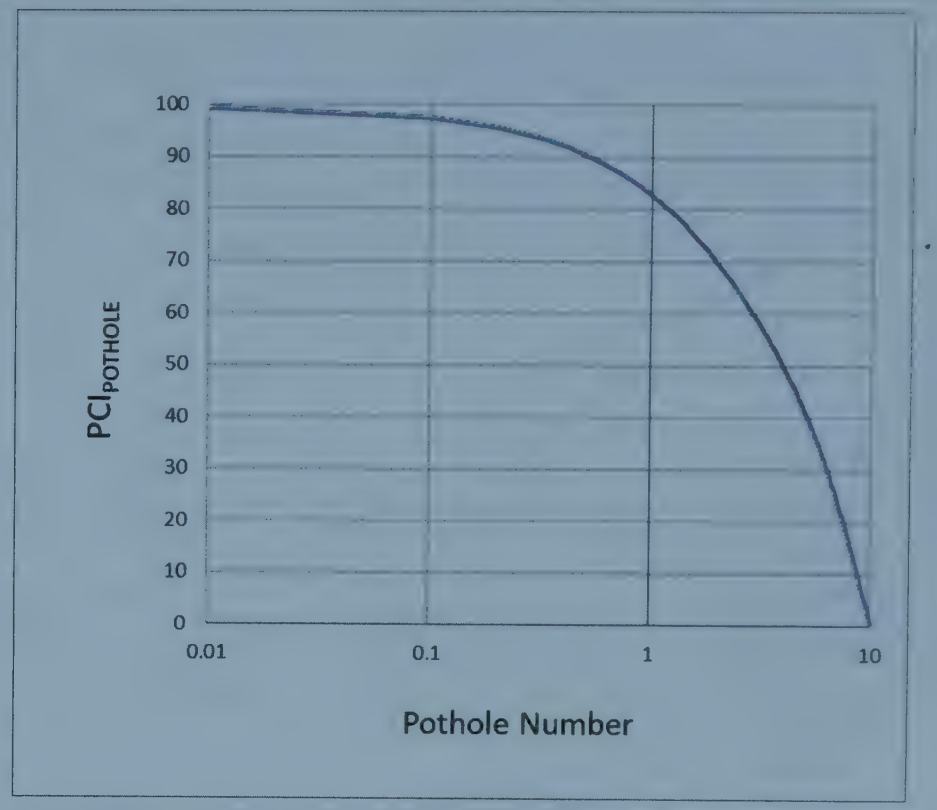
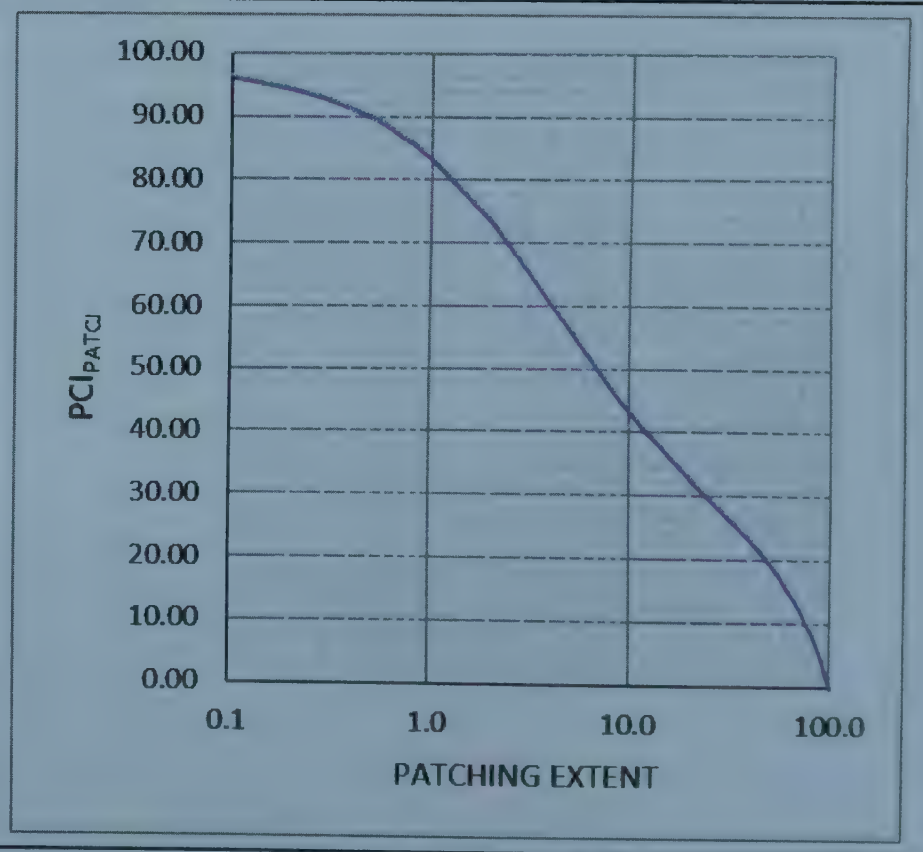
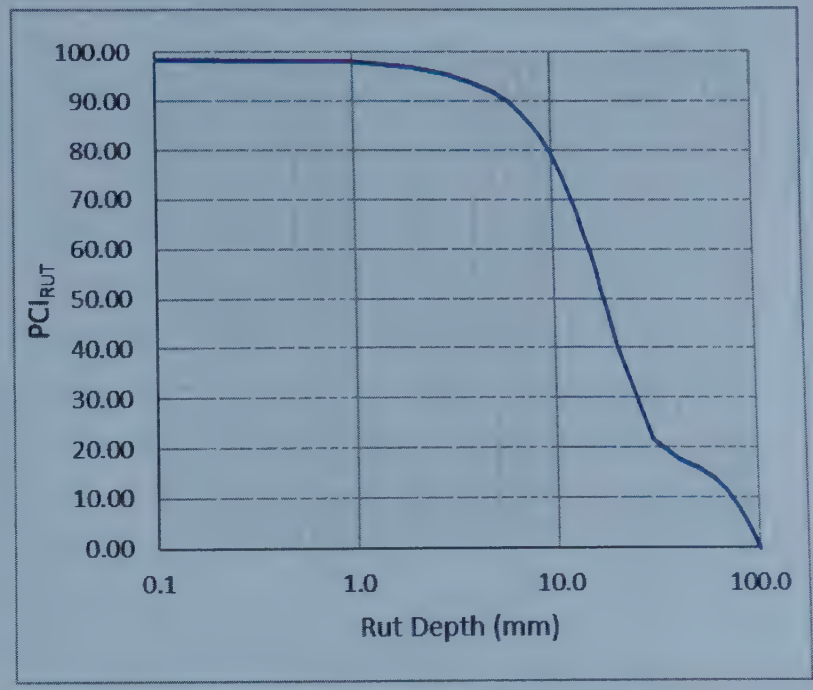
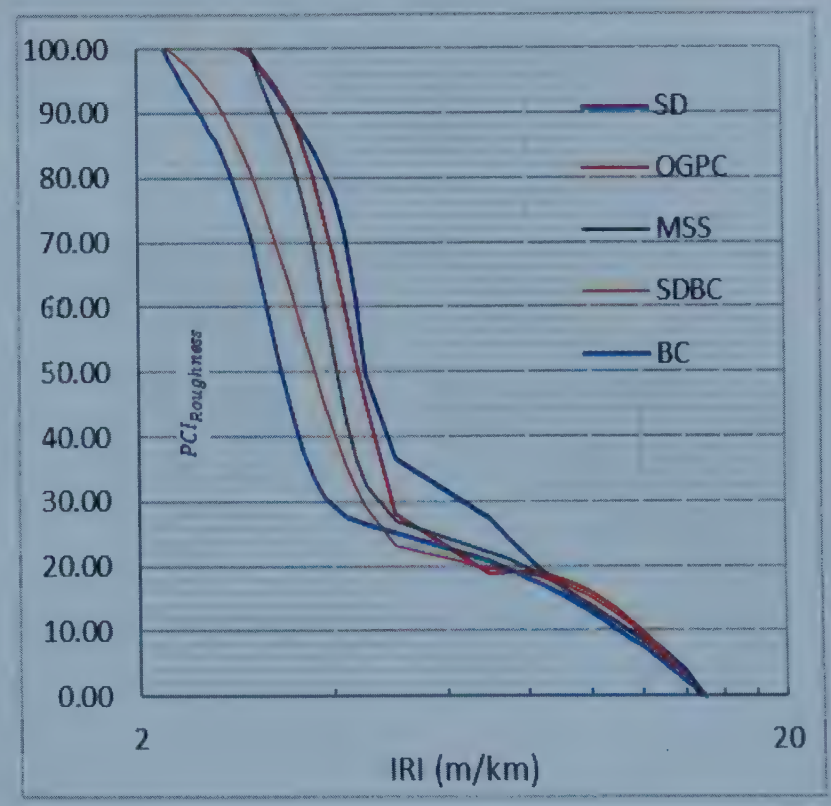
Defects (Type)	Equations	Curve
Rut Depth (mm)	$PCI_{RUT} = \frac{7231}{RD^2 - 0.737 \times RD + 73.09}$ Where RD = Rut Depth (mm)	
Roughness (IRI)	$PCI_{ROUGHNESS} = \frac{100}{IRI^{1.91} - 3.542 \times IRI + 4.315}$	

Table A2.2 PCI based Ratings for MDR and Rural Roads

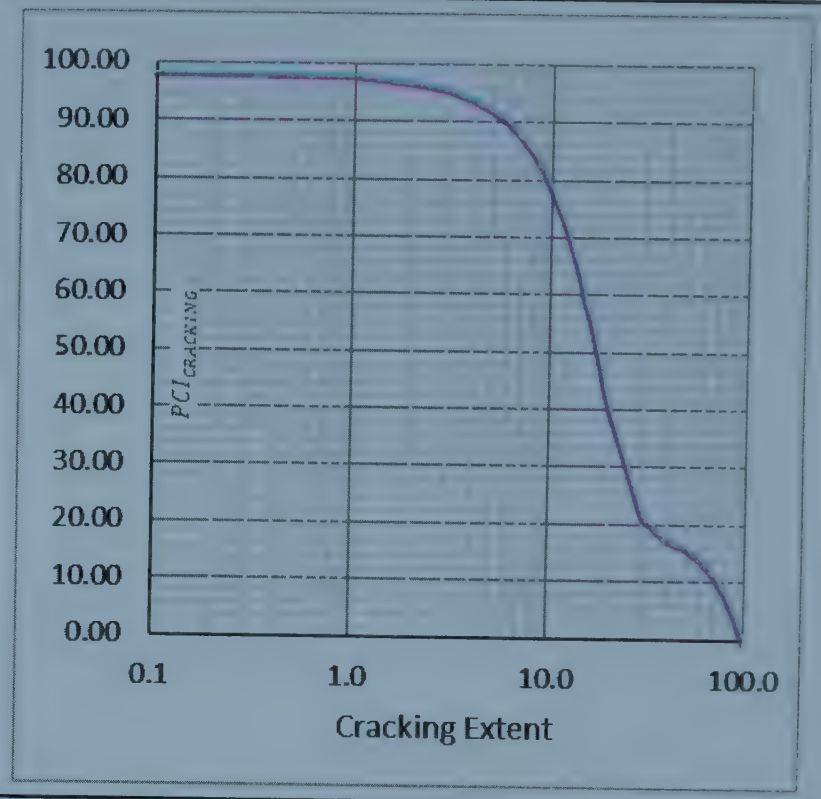
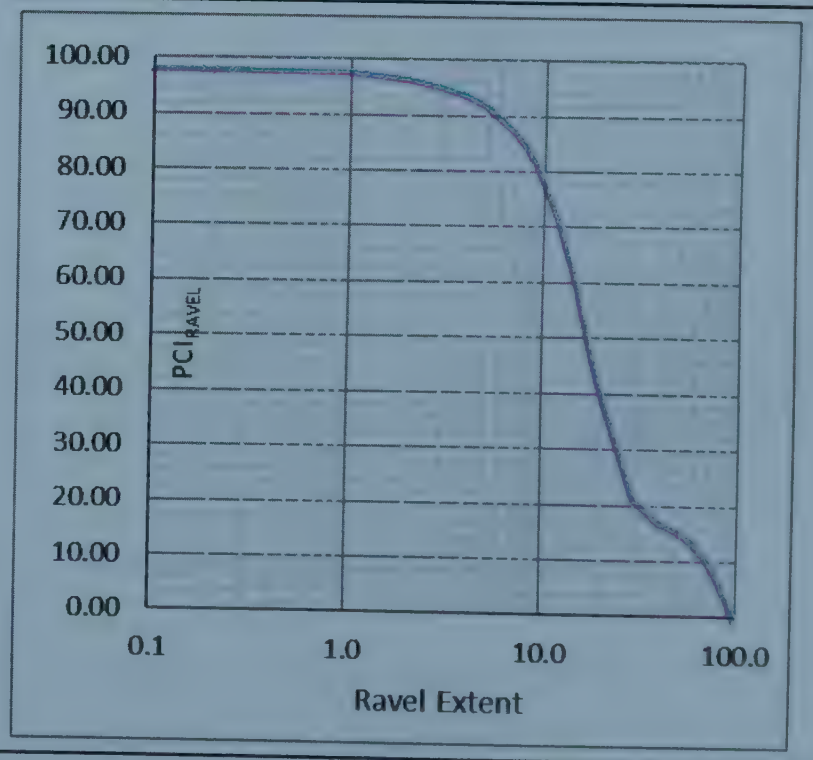
Part A (MDR)

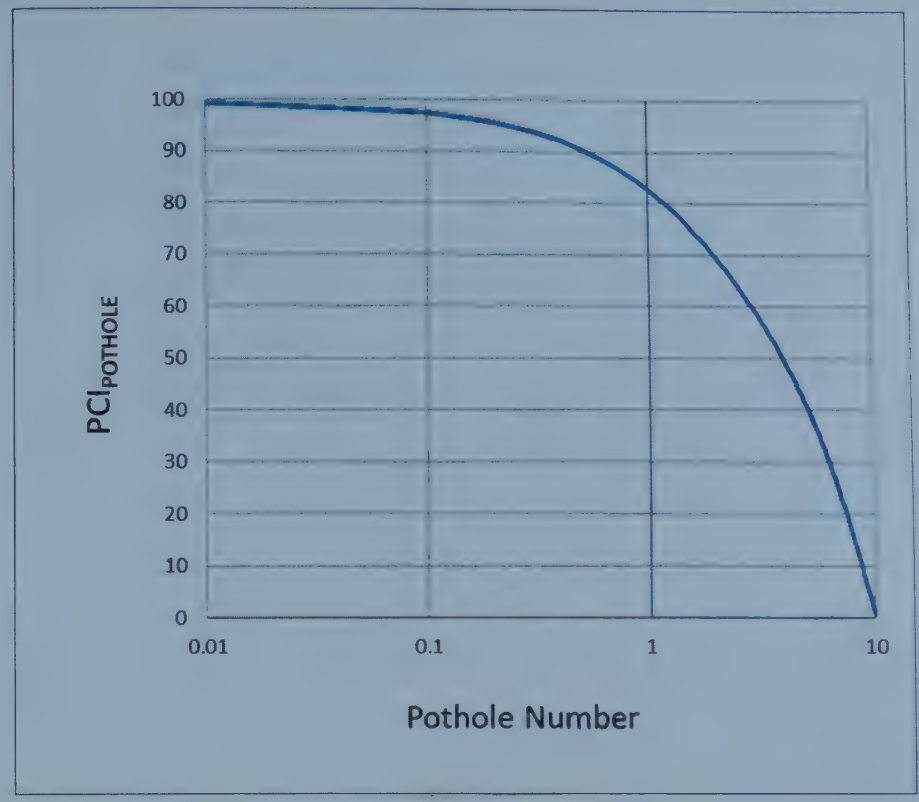
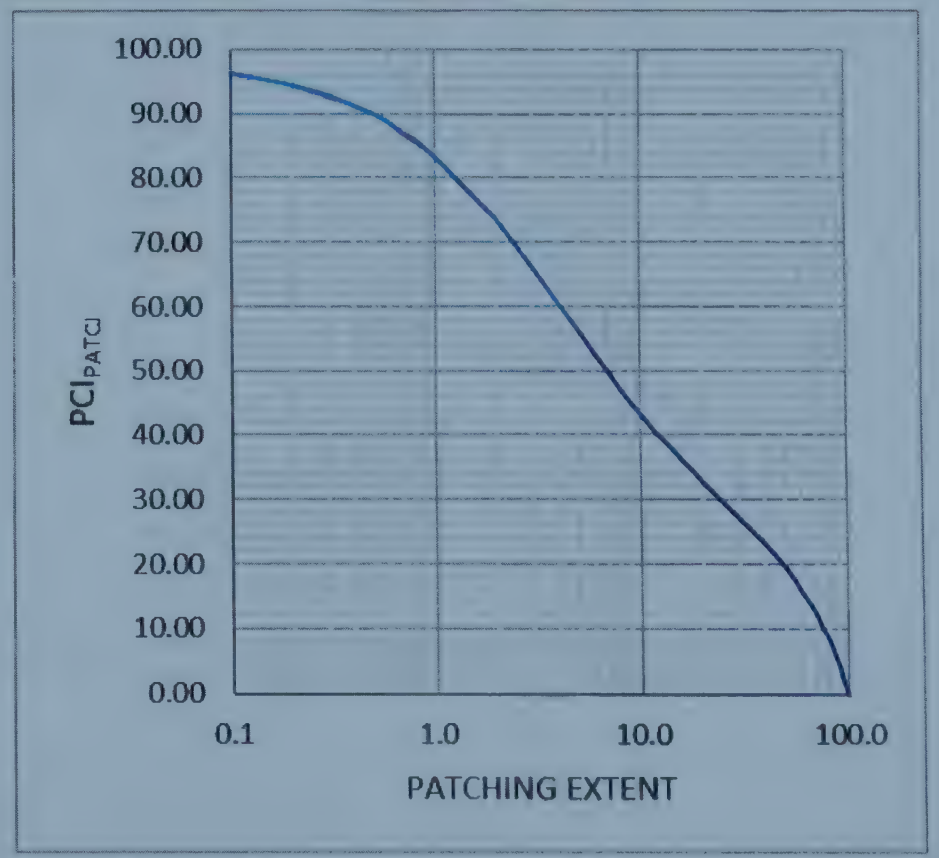
Defects (Type)	Equations	Curve
Cracking (%)	$PCI_{CRACKING} = \frac{-0.5662 \times CE^3 + 85.14 \times CE^2 - 3377 \times CE + 5.182 \times 10^4}{CE^2 - 29.31 \times CE + 523.4}$ Where CE=Crack Extent	
Ravelling (%)	$PCI_{RAVEL} = \frac{-0.5662 \times RE^3 + 85.14 \times RE^2 - 3377 \times RE + 5.182 \times 10^4}{RE^2 - 29.31 \times RE + 523.4}$ Where RE=Reveling Extent	

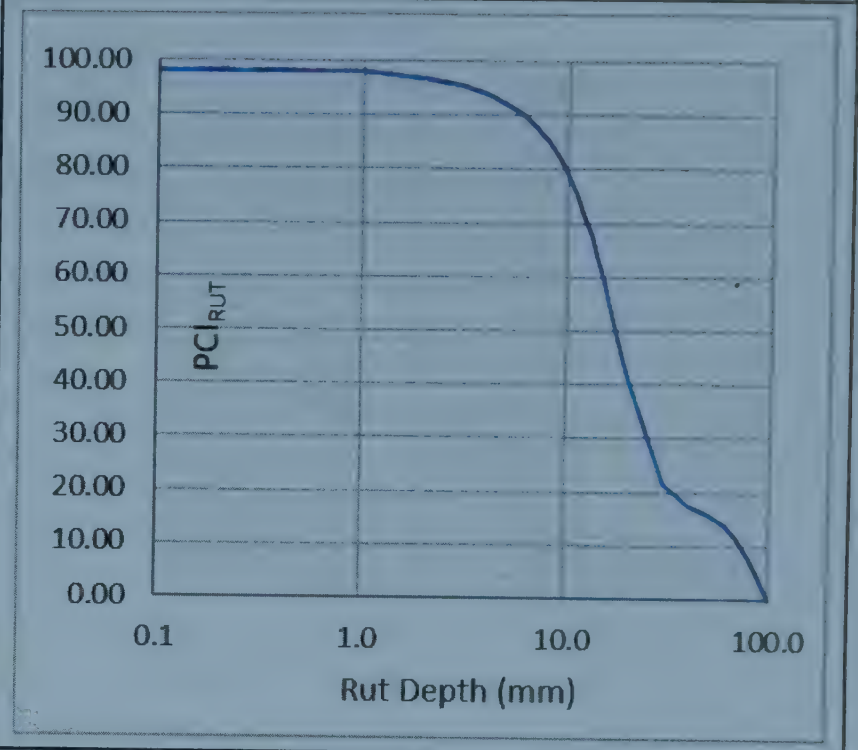
Defects (Type)	Equations	Curve
Pothole (Number)	$PCI_{POTHOLE} = 0.0113 \times PN^4 - 0.2825 \times PN^3 + 2.6246 \times PN^2 + 99.529$ Where PN=Pothole Number	
Patching (%)	$PCI_{PATCH} = \frac{-1.723 \times 10^{-3} \times PE^3 - 8.273 \times 10^{-2} \times PE^2 + 21.39 \times PE + 419.1}{PE + 4.267}$ Where PE=Patch Extent	

Defects (Type)		Equations	Curve
Rut Depth (mm)		$PCI_{CRACKING} = \frac{-0.5662 \times RD^3 + 85.14 \times RD^2 - 3377 \times RD + 5.182 \times 10^4}{RD^2 - 29.31 \times RD + 523.4}$ Where RD=Rut Depth (mm)	
Roughness (IRI)	Surface Dressing (SD)	$PCI_{Roughness} = \frac{-0.09535 \times IRI^5 + 4.235 \times IRI^4 - 74.43 \times IRI^3 + 642.4 \times IRI^2 - 2625 \times IRI + 4034}{IRI^2 - 9.065 \times IRI + 20.71}$	
	Open Graded Premix Carpet (OGPC)	$PCI_{Roughness} = \frac{-4.842 \times IRI^3 + 121.5 \times IRI^2 - 875.9 \times IRI + 2029}{IRI^2 - 8.389 \times IRI + 19.85}$	
	Mix Seal Surfacing (MSS)	$PCI_{Roughness} = \frac{-2.686 \times IRI^4 + 64.96 \times IRI^3 - 437.2 \times IRI^2 + 1046 \times IRI - 596.2}{IRI^3 - 9.766 \times IRI^2 + 31.09 \times IRI - 30.94}$	
	Semi Dense Bituminous Course (SDBC)	$PCI_{Roughness} = \frac{-4.468 \times IRI^3 + 106.2 \times IRI^2 - 694.7 \times IRI + 1507}{IRI^2 - 6.778 \times IRI + 14.51}$	
	Bituminous Concrete (BC)	$PCI_{Roughness} = \frac{-2.52 \times IRI^4 + 55.18 \times IRI^3 - 292.4 \times IRI^2 + 476.4 \times IRI - 5.565}{IRI^3 - 7.458 \times IRI^2 + 17.77 \times IRI - 12.09}$	

Part B (Rural Roads)

Defects (Type)	Equations	Curve
Cracking (%)	$PCI_{CRACKING} = \frac{-0.5662 \times CE^3 + 85.14 \times CE^2 - 3377 \times CE + 5.182 \times 10^4}{CE^2 - 29.31 \times CE + 523.4}$ Where CE=Crack Extent	
Ravelling (%)	$PCI_{RAVEL} = \frac{-0.5662 \times RE^3 + 85.14 \times RE^2 - 3377 \times RE + 5.182 \times 10^4}{RE^2 - 29.31 \times RE + 523.4}$ Where RE= Ravelling Extent	

Defects (Type)	Equations	Curve
Pothole (Number)	$PCI_{POTHOLE}=0.0113 \times PN^4 - 0.2825 \times PN^3 + 2.6246 \times PN^2 + 99.529$ Where PN= Pothole Number	
Patching (%)	$PCI_{PATCH} = \frac{-1.723 \times 10^{-3} \times PE^3 - 8.273 \times 10^{-2} \times PE^2 + 21.39 \times PE + 419.1}{PE + 4.267}$ Where PE = Patch Extent	

<table>
<tr><th colspan="2">Defects (Type)</th><th>Equations</th><th>Curve</th></tr>
<tr><td colspan="2">Rut Depth (mm)</td><td>$$PCI_{CRACKING} = \frac{-0.5662 \times RD^3 + 85.14 \times RD^2 - 3377 \times RD + 5.182 \times 10^4}{RD^2 - 29.31 \times RD + 523.4}$$
Where RD=Rut Depth (mm)</td><td rowspan="4"> 
</td></tr>
<tr><td rowspan="4">Roughness (IRI)</td><td>Surface Dressing (SD)</td><td>$$PCI_{Roughness} = \frac{-25.68 \times IRI^3 + 646.2 \times IRI^2 - 4465 \times IRI + 9408}{IRI^2 - 9.272 \times IRI^2 + 21.13 \times IRI + 3.037}$$</td></tr>
<tr><td>Open Graded Premix Carpet (OGPC)</td><td>$$PCI_{Roughness} = \frac{-4.02 \times IRI^3 + 98.33 \times IRI^2 - 670.6 \times IRI + 1444}{IRI^2 - 8.215 \times IRI + 17.79}$$</td></tr>
<tr><td>Mix Seal Surfacing (MSS)</td><td>$$PCI_{Roughness} = \frac{-24.69 \times IRI^3 + 593.2 \times IRI^2 - 3663 \times IRI + 6786}{IRI^3 + 7.173 \times IRI^2 - 9.017 \times IRI + 15.43}$$</td></tr>
<tr><td>Semi Dense Bituminous Course (SDBC)</td><td>$$PCI_{Roughness} = \frac{25.16 \times IRI + 48.45}{IRI^2 - 5.079 \times IRI + 7.595}$$</td></tr>
</table>

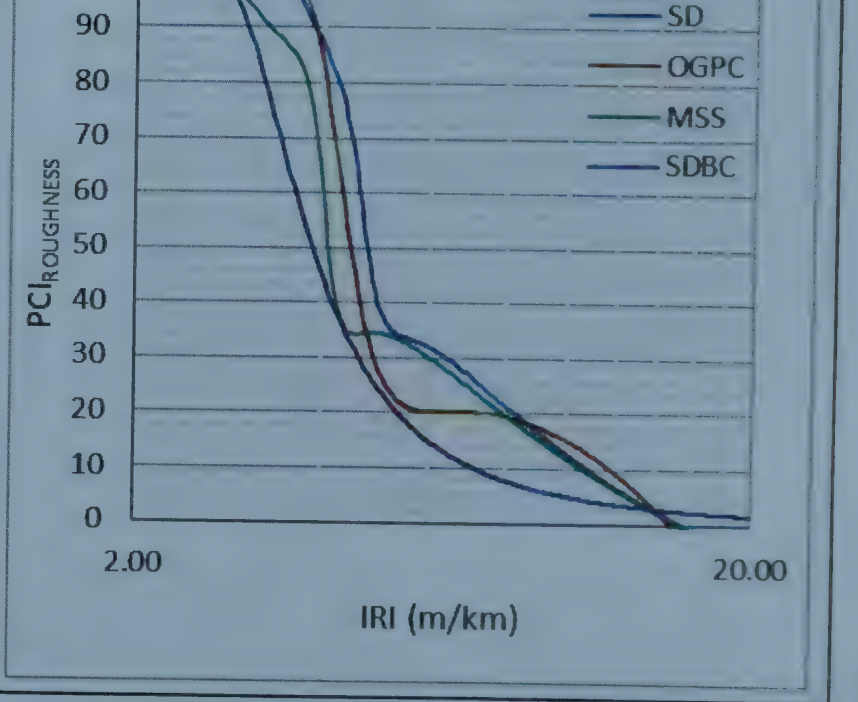
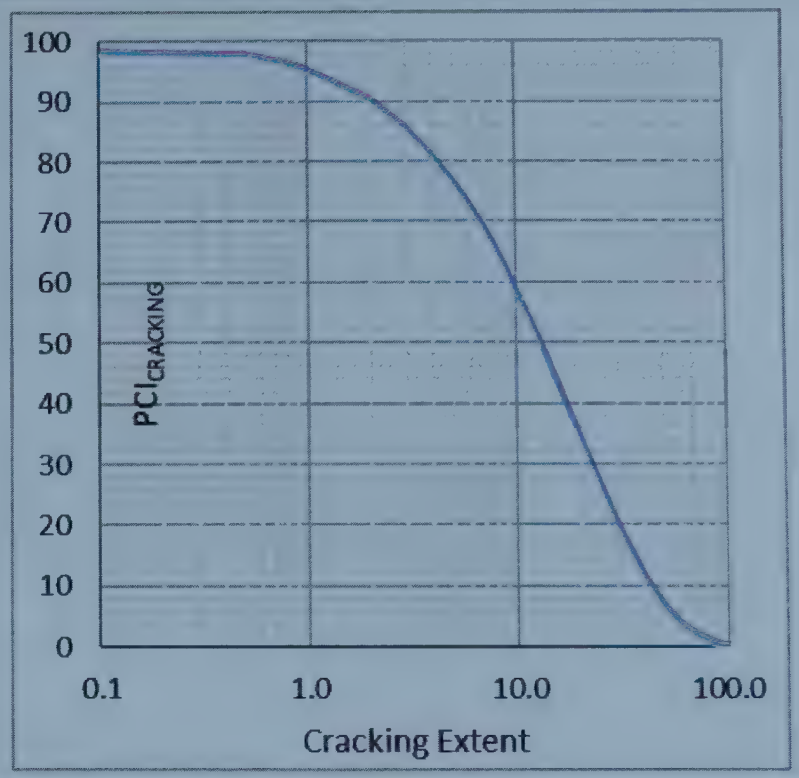
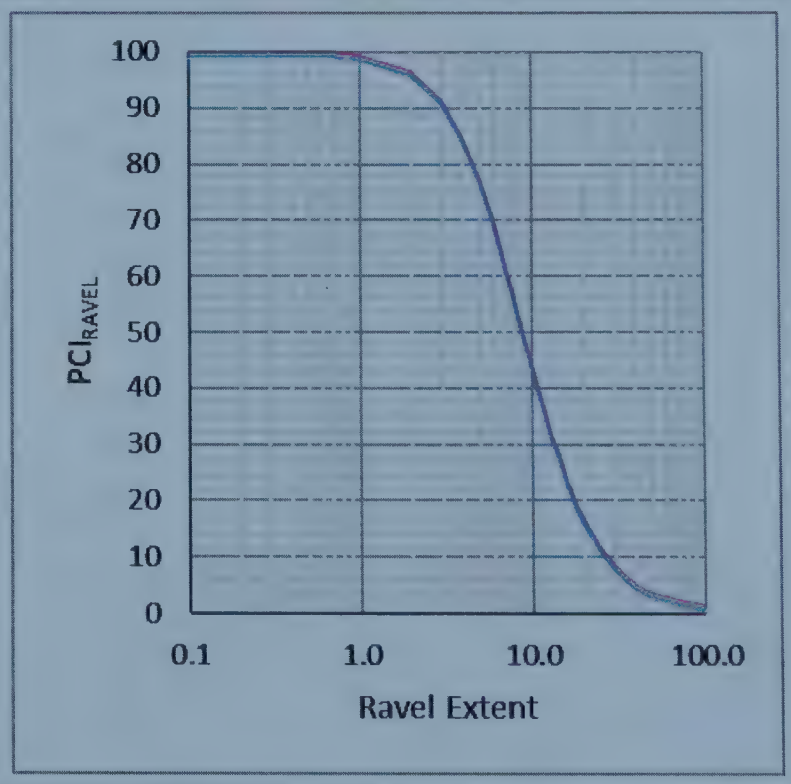
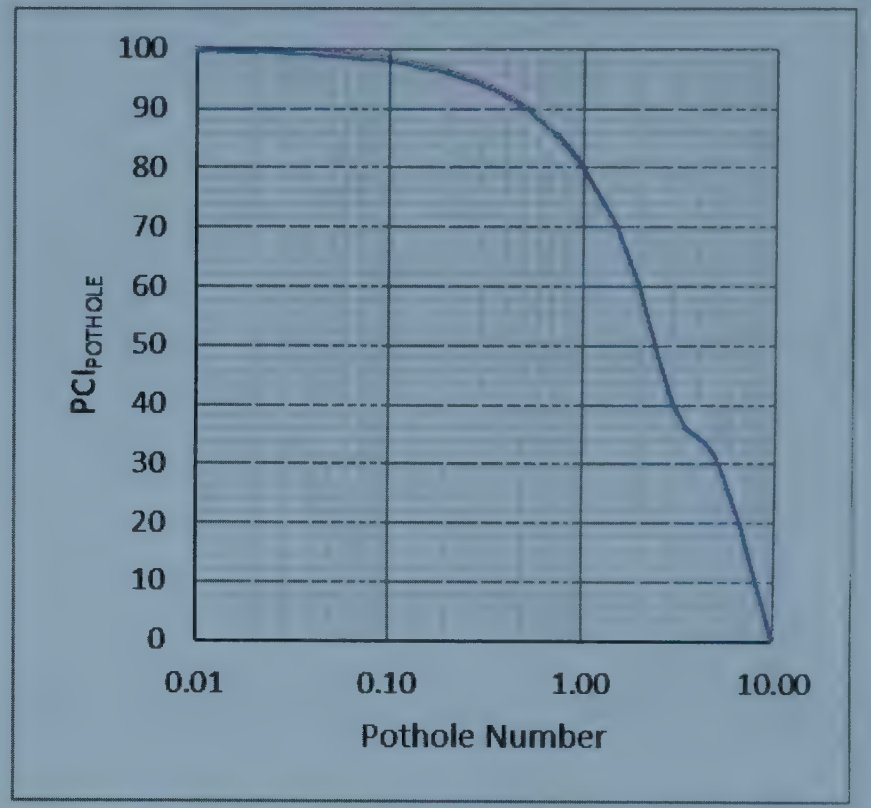
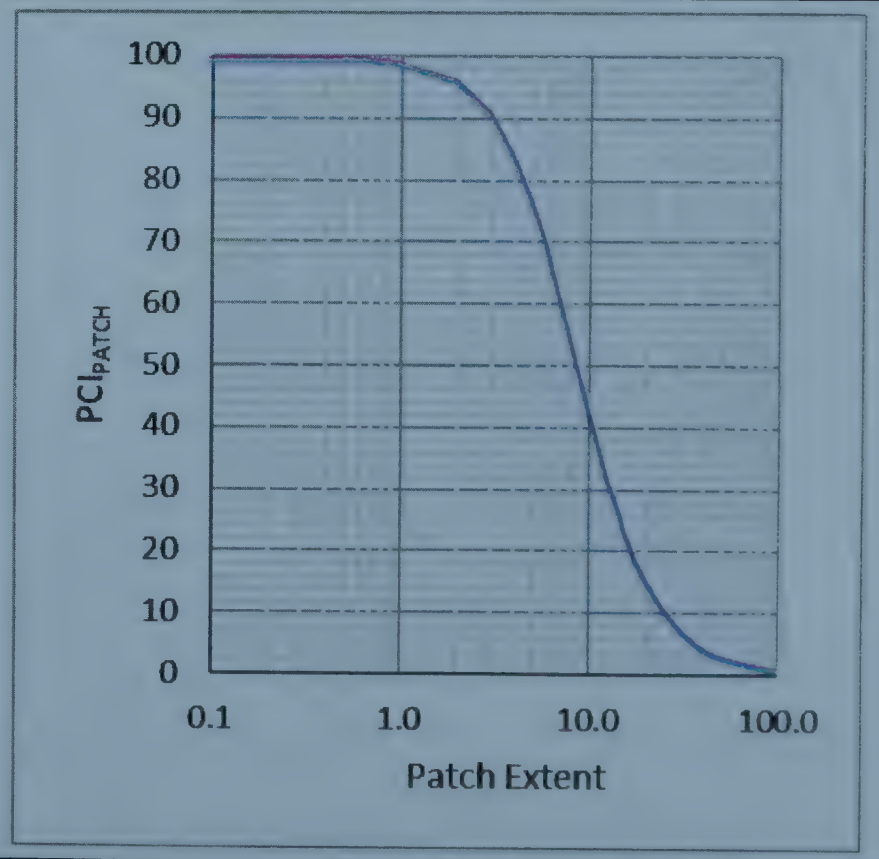
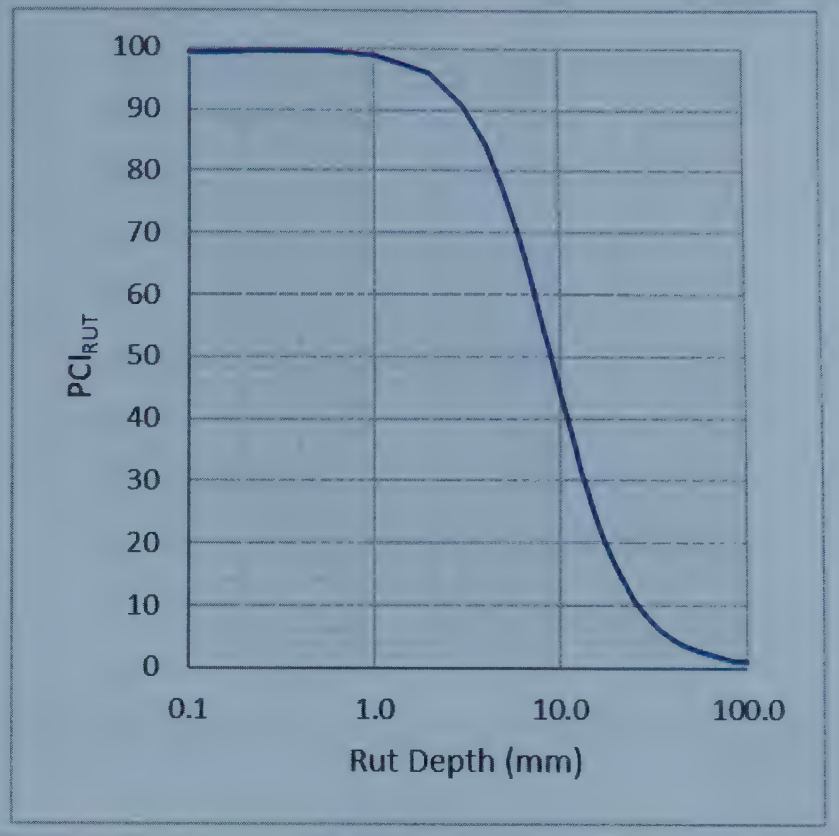
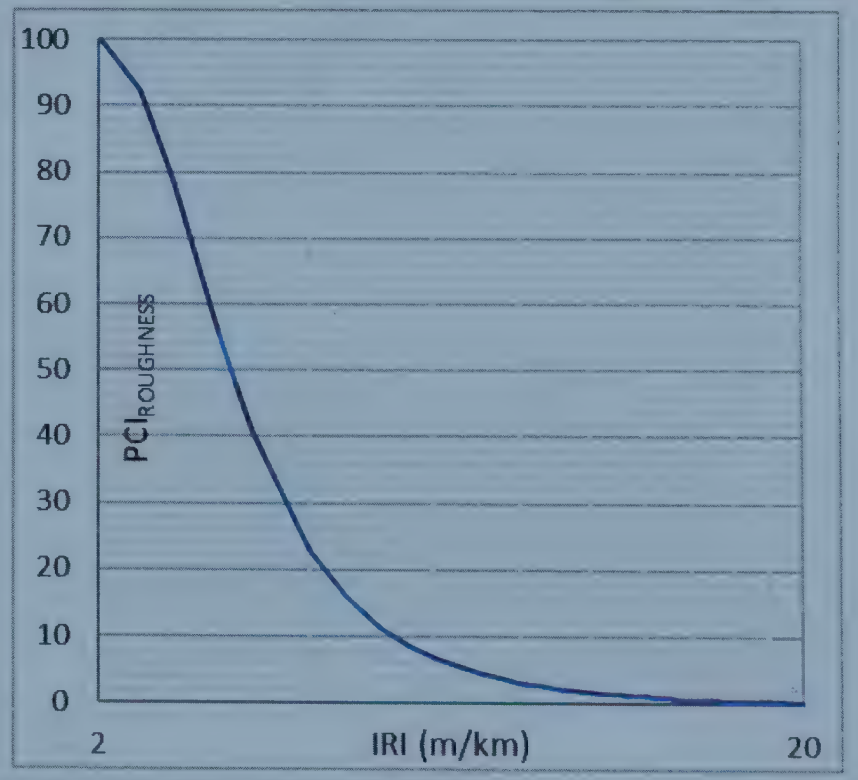


Table A2.3 PCI based Ratings for Urban Roads

Defects (Type)	Equations	Curve
Cracking (%)	$PCI_{CRACKING} = 100 \times e^{[-0.0534 \times CE']} - 0.006641 \times CE$ Where CE=Crack Extent	
Ravelling (%)	$PCI_{RAVEL} = \frac{7231}{RE^2 - 0.737 \times RE + 73.09}$ Where RE= Ravelling Extent	

Defects (Type)	Equations	Curve
Pothole (Number)	$PCI_{POTHOLE} = \frac{-130.6 \times PN^3 + 2112 \times PN^2 - 9550 \times PN + 14390}{PN^3 + 6.619 \times PN^2 - 66.73 \times PN + 144.1}$ Where PN= Pothole Number	
Patching (%)	$PCI_{PATCH} = \frac{7231}{PE^2 - 0.737 \times PE + 73.09}$ Where PE = Patch Extent	

Defects (Type)	Equations	Curve
Rut Depth (mm)	$PCI_{RUT} = \frac{7231}{RD^2 - 0.737 \times RD + 73.09}$ Where RD= Rut Depth (mm)	
Roughness (IRI)	$PCI_{ROUGHNESS} = \frac{100}{IRI^{1.91} - 3.542 \times IRI + 4.315}$	

1. Examples

A. Highways: Expressways, National Highways and State Highways

A.1 Excellent to Good Category Road

S. No.	Parameter	Extent, %	PCI	Maintenance Recommendations
1.	Cracking (%)	0.5	93.58	Routine Maintenance
2.	Ravelling (%)	0.3		
3.	Potholes (Number)	0		
4.	Patching (%)	0.05		
5.	Rut Depth (mm)	0.10		
6.	IRI (m/km)	2.4		

A.2 Satisfactory to Fair Category Road

S. No.	Parameter	Extent, %	PCI	Maintenance Recommendations
1.	Cracking (%)	5	41.37	Minor Rehabilitation (based on structural evaluation)
2.	Ravelling (%)	3		
3.	Potholes (Number)	2		
4.	Patching (%)	2.6		
5.	Rut Depth (mm)	10		
6.	IRI (m/km)	4.5		

A.3 Poor to Fail Category Road

S. No.	Parameter	Extent, %	PCI	Maintenance Recommendations
1.	Cracking (%)	14	20.54	Major Rehabilitation/ Structural Overlay
2.	Ravelling (%)	12		
3.	Potholes (Number)	4		
4.	Patching (%)	15		
5.	Rut Depth (mm)	14		
6.	IRI (m/km)	8		

B. MDR and RR: Major Districts Roads and Rural Roads

B.1 Excellent to Good Category Road

S. No.	Parameter	Extent, %	PCI	Maintenance Recommendations
1.	Cracking (%)	0.6	89.45	Preventive Maintenance
2.	Ravelling (%)	0.1		
3.	Potholes (Number)	1		
4.	Patching (%)	0.5		
5.	Rut Depth (mm)	1		
6.	IRI (m/km)	2.8		

B.2 Satisfactory to Fair Category Road

S. No.	Parameter	Extent, %	PCI	Maintenance Recommendations
1.	Cracking (%)	6.5	47.17	Minor Rehabilitation (based on structural evaluation)
2.	Ravelling (%)	4.7		
3.	Potholes (Number)	6		
4.	Patching (%)	6		
5.	Rut Depth (mm)	8		
6.	IRI (m/km)	9.2		

B.3 Poor to Fail Category Road

S. No.	Parameter	Extent, %	PCI	Maintenance Recommendations
1.	Cracking (%)	20	22.44	Major Rehabilitation/ Structural Overlay
2.	Ravelling (%)	16		
3.	Potholes (Number)	10		
4.	Patching (%)	12		
5.	Rut Depth (mm)	22		
6.	IRI (m/km)	12		

C. Urban Roads

C.1 Excellent to Good Category Road

S. No.	Parameter	Extent, %	PCI	Maintenance Recommendations
1.	Cracking (%)	0.5	96.1	Routine Maintenance
2.	Ravelling (%)	0.2		
3.	Potholes (Number)	0		
4.	Patching (%)	0.1		
5.	Rut Depth (mm)	0		
6.	IRI (m/km)	2.4		

C.2 Satisfactory to Fair Category Road

S. No.	Parameter	Extent, %	PCI	Maintenance Recommendations
1.	Cracking (%)	5	56.86	Minor Rehabilitation (based on structural evaluation)
2.	Raveling (%)	2		
3.	Potholes (Number)	3		
4.	Patching (%)	3.5		
5.	Rut Depth (mm)	4		
6.	IRI (m/km)	6		

C.3 Poor to Fair Category Road

S. No.	Parameter	Extent, %	PCI	Maintenance Recommendations
1.	Cracking (%)	12	34.68	Major Rehabilitation/ Structural Overlay
2.	Ravelling (%)	8		
3.	Potholes (Number)	4		
4.	Patching (%)	10		
5.	Rut Depth (mm)	12		
6.	IRI (m/km)	7		

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/Manual, etc. from the date specified therein)

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